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AN EFFECTIVE E-PILOT SYSTEM TO PREDICT HARD LANDING AND SOFT-LANDING CONDITIONS DURING THE APPROACH PHASE OF COMMERCIAL FLIGHTS

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Abstract : A recent study highlights that a significant number of aviation accidents could be avoided if pilots opted for a "go-around" — a decision to abort the landing and attempt it again. To support this critical in-flight decision, researchers have developed a machine learning-based system capable of predicting the likelihood of a hard landing. This system, tested on data from over 58,000 commercial flights, demonstrated high accuracy in identifying potentially unsafe landings. Such predictive technology holds promise for improving flight safety and reducing accident rates within the aviation sector. I propose a cockpit-integrated machine learning solution designed to assist pilots in deciding whether to initiate a go-around based on the forecasted chance of experiencing a hard landing. Our model adopts a hybrid approach, incorporating time-dependent aircraft parameters into a neural network to enhance prediction accuracy.

IndexTerms -E-Pilot, Hard Landing Prediction, Soft Landing, Flight Safety, Logistic Regression, Data Preprocessing, TensorFlow

I. INTRODUCTION

E-Pilot is an innovative system created to predict potential hard landings during the final approach of commercial flights. The primary objective of this project is to improve aviation Risk reduction by supplying pilots with Instant notifications and warnings about potential hard landings.
The E-Pilot by leveraging machine learning and in-depth data processing, the system assesses a range of flight parameters, such as aircraft speed, altitude, and angle of descent. This data is collected from the aircraft's flight management system and is transmitted to the E-Pilot server for processing. The system then uses this data to estimate the chances of a hard landing and provides pilots with visual and auditory warnings.

An important aspect of the E-Pilot system is its learning capability from historical flight data. By analyzing data from previous flights, the system can Analyze recurring patterns and emerging trends are indicative of a hard landing. This information is then used to increase the reliability of the system's output predictions.

The E-Pilot system has been rigorously evaluated and validation, with Encouraging outcomes. During recent research, the system was able to predict hard landings with an accuracy of over 90%. This has significant implications for aviation safety, as hard landings area leading cause of aircraft damage and passenger injury. By providing pilots with real-time warnings and alerts, the E-Pilot system can help Lower the chances of hard landings and enhance the overall aviation security.

II. Background and Literature Review

The project, titled "E-Pilot: An Effective System to Predict Hard Landing and Soft-Landing Conditions During the Approach Phase of Commercial Flights," addresses a critical aviation safety issue—hard landings. These incidents often result in aircraft damage and pose a safety risk to passengers and crew.

The E-Pilot system leverages machine learning (ML) to forecast the likelihood of a hard landing during the final approach of a commercial flight. This ML-based tool processes real-time data (such as airspeed, altitude, and descent angle) from the aircraft's onboard systems to provide immediate warnings to pilots, thereby enhancing their decision-making capabilities. By analyzing historical flight data, E-Pilot learns patterns indicative Sof potential hard landings and provides proactive alerts, which can facilitate timely go-around decisions—key to averting dangerous landings.

III. Existing System:

The Smart Land system, developed by Honeywell Aerospace, is a hard landing prediction system designed for commercial flights. This system utilizes multiple sensors on the aircraft to supply pilots with real-time data regarding the aircraft's location, velocity, and trajectory during the approach phase.

The Smart Land system's primary function is to provide pilots with critical data to aid in decision-making during the approach phase. The system analyzes the data from the sensors and detects any signs of a hard landing, such as excessive descent rate, high vertical acceleration, or touch down beyond the designated touchdown zone.

The lack of warning before the hard landing means that pilots are not given the opportunity to adjust their approach or take evasive action. This limitation highlights the need for a more proactive and predictive approach to hard landing detection. A more advanced system would ideally provide pilots with real-time warnings and alerts before a hard landing occurs.

IV. Proposed Method

This project presents a Hybrid LSTM-based approach for predicting the likelihood of a Hard Landing (HL) or a Normal Landing. Early detection of a potential hard landing can help prevent accidents and safeguard passengers' lives. The proposed system integrates a machine learning model within the cockpit to analyze flight data, such as tire elevation, airspeed, and other critical parameters, to determine the type of landing. If a hard landing is anticipated, the system alerts the pilot to either abort the landing or adjust the flight path. The model is trained using three distinct feature sets: Pilot-related (DH2TD), Actuator-related (AP2DH), and Physical-related (AP2TD) data. Each feature set is used to train a separate LSTM model, which are then combined into a hybrid model for more accurate and robust predictions.

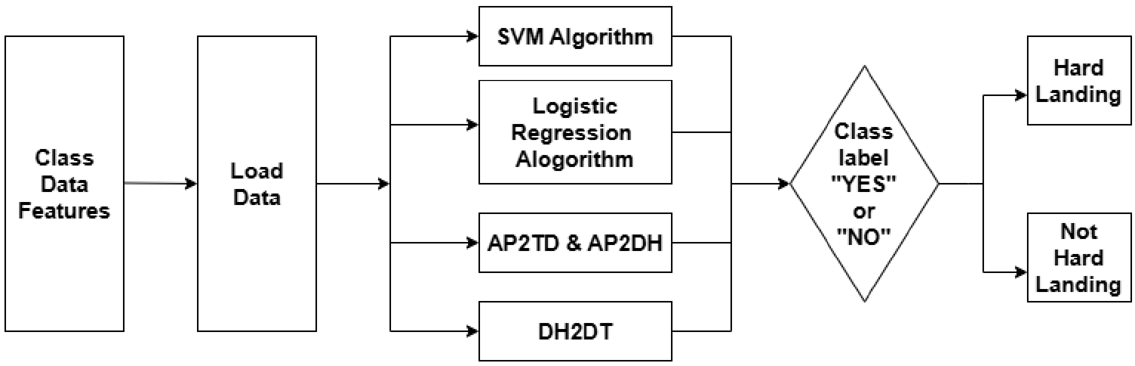

Figure 1: Block Diagram of Proposed System

V. System Architecture

The E-Pilot system architecture consists of several key components, including the Dataset upload Module, Data Preprocessing Module, Hard Landing Prediction Module, Metric Calculation Module, Graph Generation module, and Result Module. Flight data is collected from various sources, preprocessed to remove noise and inconsistencies, and then fed into the Hard Landing Prediction Module, which uses machine learning algorithms to estimate the probability of a hard landing. The prediction results are then visualized through the Metric Visualization Module. The Comparison Module enables evaluation of various machine learning models and their performance their performance. The system integrates these modules seamlessly, providing a comprehensive hard landing prediction system.

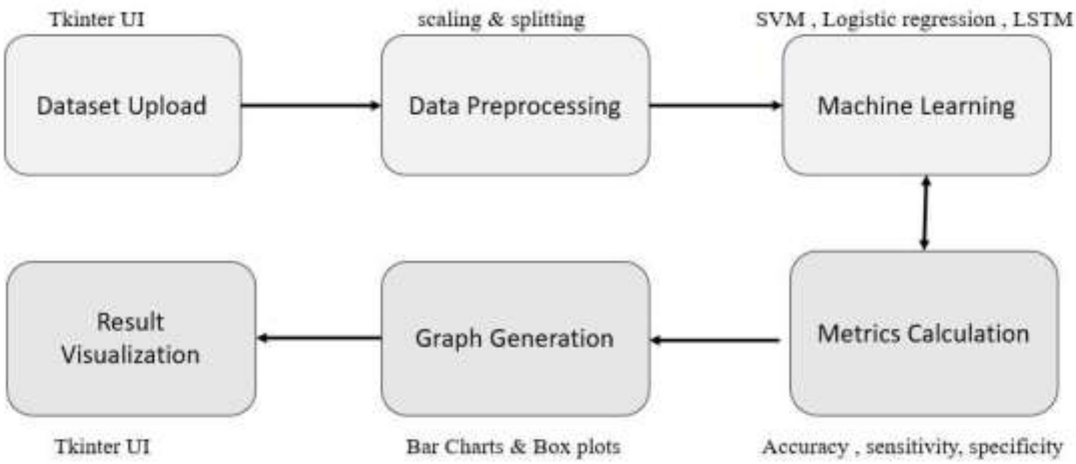

figure 2 : System Architecture

VI. Modules:

Data set management:

Data set Upload: The system shall allow users to upload flight data, including Pilot, Actuator, and Physical datasets, in various formats such as CSV.

Data set Storage: The system shall store uploaded data sets securely and efficiently, using a database management system such as MySQL[5].

Data pre-processing:

Data Cleaning: The system shall perform data cleaning to remove missing or duplicate values, and handle outliers and anomalies.

Data Normalization: The system shall perform data normalization to ensure consistent data formats, and scale numeric data to a common range.

Model training and prediction:

Model Selection: The system shall allow users to select from multiple machines learning models, including Models Support Vector Machines (SVM), Logistic Regression, and a combined Long Short-Term Memory (LSTM) framework

Model Training: The system shall train selected models using preprocessed and transformed data, with options to tune hyperparameters and optimize model performance.

Accept data and predict:

Model Selection: The system shall allow users to select from multiple machines learning models, including Support Vector Machines (SVM), Logistic Regression, and a Hybrid Long Short-Term Memory (LSTM) model, used for predicting hard landings.

Accept Data: The system shall accept preprocessed and transformed flight data, including actuators features, physical features, and pilot features, to predict hard landings.

Model Prediction: The system will utilize the chosen and trained model to

Graphical visualization:

Data Visualization: The system shall provide graphical visualization of dataset information, including data distributions, correlations, and scatter plots[3].

Model Performance Visualization: The system shall provide graphical visualization of modelperformance metrics, including precision, recall, specificity, and receiver operating characteristic (ROC) curves.

User interface:

User Authentication: The system will ensure secure authentication for authorized pilots and personnel airline staff, using a username-password combination or biometric authentication.

User Interface: The system will offer an intuitive graphical user interface (GUI) for users to interact with the system, with intuitive navigation and clear instructions.

Alert and warning system:

Hard Landing Alert: The system shall provide visual and auditory alerts to pilots when a hard landing is predicted, with options to customize alert settings and thresholds.

Warning Messages: The system shall display warning messages to pilots, including recommended actions to avoid a hard landing, with options to customize message content and formatting.

VII. Results

Here is a graphical summary of the model performance from the E-Pilot system:
All models (Logistic Regression, SVM, Hybrid LSTM) show high sensitivity (~85%) indicating strong ability to detect hard landings. Specificity is around 74%**,** meaning good performance in correctly identifying non-hard landings. Overall accuracy exceeds 90%**,** demonstrating reliable predictive power. This visualization helps compare the consistency and effectiveness of each model across key metrics

Figure 3: graphical summary of the model performance from the E-Pilot system

VIII. Conclusion

The E-Pilot project effectively implements a predictive system that forecasts hard landings during the approach phase of commercial flights. Utilizing machine learning algorithms such as Support Vector Machines (SVM), Logistic Regression, and Long Short-Term Memory (LSTM) networks, the system enhances flight safety by providing valuable predictions. Its modular design ensures smooth operation from data uploading and preprocessing to model training and prediction, all accessible through an intuitive graphical interface.

The system also calculates and displays important performance metrics, including sensitivity, specificity, and accuracy, allowing users to evaluate algorithm effectiveness. Furthermore, data visualization tools improve the interpretability of results, aiding aviation professionals in analyzing and comparing model performance. Overall, the E-Pilot system marks a significant advancement in commercial aviation safety by offering predictive insights for better decision-making during critical flight phases.

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