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Intelligent Avionics System Onboard An Aircraft Enhancing Communication

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Abstract. Communications connect the flight deck to the ground and the flight deck to the passengers. On-board communications are provided by public-address systems and aircraft intercoms. Inefficient communication may lead to a catastrophe risking lives and resources. SKYVOIX, an intelligent system on board that enhances safety and improves the communication of the aircraft by reducing human error and increasing the awareness. The system is intended to be centralized and installed in addition to the current systems. With high air traffic and busy airspace, the transmissions are often misheard causing communication failure which is undesirable. A backup for enabling communication with the ground in emergencies is required which ensures active transmissions and is intelligent enough to handle the gravity of situation. The passengers who are often unaware about the routine and emergency protocols, busy with their electronics, listening to music cutting them off with the environment shall be benefited. The system works on encrypted conversions in real time converting ATC, cabin crew’s instructions and delivering apt information to appropriate sections which is achieved by Deep learning framework TensorFlow. The system shall also be used for real time flight planning by ATC based upon traffic density. The stability of the system is studied with effective layouts reducing the errors and maintaining the overall neutrality. The on-board data shall be stored, analyzed which shall help in the maintenance and crash investigations. The system proves to be efficient, reliable and practical enhancing the aviation safety and communication that can never be compromised in aviation.

1. Introduction

With advancements in aviation technologies the skies have become a reliable channel for transportation be it for commercial sector, private or public. Safety has always an important factor which plays a major role in aviation and has no room for error. The industry is expanding with 3.7% annual Compound Average Growth Rate forecasting passenger demand to double in next 20 years which refers to increase in air traffic demanding more resources like aircrafts, man power, ground facilities and most importantly the airspace which is difficult to expand. The airspace can either be expanded 1. In height, this shall involve the development of new technologies for engines and airframes considering the economics that may take many years or, the other option 2. Along the span, which is hindered by the fact of earth being 71% of water over which the controlling the traffic is difficult and the policies of the air carriers and regional airspace. The only possible solution is the evolution of better technologies that could help aviation progress by handling future parameters with high efficiencies and standards. The aircraft should possess advanced sensing, computing and communications, networking capabilities as well as onboard systems integration and software modules. It is envisioned to robustly participate as an intelligent node in a global network of air, satellite, ground systems, ensuring quality information correctly, and reliably reaches the right place at
the right time for processing and decision making[1]. This work emphasizes on the system design to increase safety standards by improvement in the avionics. Intelligent avionics are such systems that can process their computations making the interface versatile, accurate and producing data which can further be processed explicitly. Convolutional Neural Networks are implemented and accordingly the system is designed which can be implemented. The architecture of the system, methods of data acquisition are defined that enables stable and secure data stream and synthesis. The CNN are implemented through TensorFlow a deep learning library and an application solution for the passenger IFE system is described and developed using Android Studio.

2. Claims

The objective of the work is to establish a secure communication system that processes on the ATC communications, in-flight communication, and flight data in real time using Deep learning, Big Data analytics, Error correction, Neural networks. The system design is conceptualized that shall address the following:

1. Smart IFE (In-Flight Entertainment) and notification systems
2. ATC radio communication systems
3. Flight data Synthesis

3. Description:

3.1 SKYVOIX IFE system and Flight Data Synthesis

Some aircrafts are equipped with IFE systems and some are not in order to save the costs. The system is important not only for entertainment but majorly for cabin announcements and instructions. SKYVOIX system shall help in creating awareness during the important phases of flight and emergencies and also provide entertainment feed. Safety always comes first and nowadays passengers prefer to isolate themselves from the environment by using earphones plugged to their devices, poses major risk which has not been addressed yet. The system shall convert the cabin announcements to text in passenger's preferred language and display on their Wi-Fi enabled device. If the aircraft or the device is not Wi-Fi enabled, a user based application is designed that is discussed later. This system shall help in cutting costs by residing over the current IFE systems which are being replaced by Wi-Fi IFE. The system helps in removing the passenger units, SEB's and wiring.

3.1.1 System specifications

1. Diverse architecture
2. Deep learning based real time audio to text converter of multilingual capabilities
3. Compatible with satellite linkage and current IFE systems
4. Converter can be used irrespective of aircraft being Wi-Fi enabled
5. Dedicated user’s end application
3.1.2 Physical architecture

The architecture of the system is simple and separate. It is directly fed to the raw analogous audio data from different sources. The design is such that the total stability of the circuit is maintained and data is securely processed and propagated. The schematic diagram of the system is synthesized to describe the processes and hardware required. For the data to be accurate and easy to process is encrypted and converted to digital format using the A/D converter and then is processed through the error control algorithm into the converter after which it is post processed and fine tuned through the D/A converter for obtaining readable format, then is compressed and stored. All these processes take place in a single unit. This converter unit is connected to the Display systems and the Wi-Fi system for the output. The unit can be modified and programmed according to the need of the air carrier for instance updating of the entertainment data base like movies, songs. With this architecture all the announcements and cockpit recordings can be stored and locally and on the connected devices which can be transmitted in real time. This method is used for Flight Data Synthesis.

![Figure 1 SKYVOIX IFE System](image)

3.2 ATC Communication System

With increasing air traffic, the airspaces are becoming congested and causing slow movement of traffic. The ATC communication over radio being transmitted in heavy traffic is difficult for the pilots as well as the controllers to follow. For this problem the solution of text to audio conversion is implemented. This section is in CROSS-REFERENCE TO the application US 11/934,607 of James J. Foskett[2] which is about the method of implementation but in contrary SKYVOIX is modified system that processes the transmission and refines it using error control codes such that no data is lost and uses deep neural networks for audio to text conversion. The data is sequenced securely avoiding the mixing and can be reviewed in real time with an informative system logging and displaying airplane’s
response. These changes are defined for accurate, fast and secure information propagation. The data transmitted between both the terminals are stored and can be processed for analysis for preparation of accurate flight paths in real time according to traffic density. This type of data comes under BIG DATA and can be processed and analyzed using frameworks like Hadoop, Spark or the Deep learning frameworks like Theano, Keras and TensorFlow.

3.2.1 Physical architecture

In this system the same SKYVOIX IFE and audio to text converter is used. For the system to establish the communication, architecture is defined at both the terminals (The ATC and the aircraft).

![Figure 2 SKYVOIX ATC COMMUNICATION System](image)

The architecture is mapped and shown in the form of a figure. The additional hardware required would be the storage facility at the ATC end and the information handling unit as well processing units at the both ends.

![Figure 3 Information Handling And Response](image)
The architecture of the Information handling and response is mapped in the figure. This system is compatible to be used with CPDLC and resides over its limitations. Like the controller settings, the settings can be changed in the aircraft as well. With the unit of data processing and analysis the power is given to the computers to alter and provide best flight paths to reduce congestion of the air traffic in real time. The communication channel between both can be even radio or satellite. For the radio type the data has more chances of error so requires power and thorough refining. All the transmissions are stored securely for a limited period and can be even monitored in real time.

3.3 Materials

Materials required would be used for two functions one for the storage and the other for the protections such that there is no hindrance in the communication process. The materials with this capabilities are the Graphene based Nanocomposites that most importantly have the ability to store the data howsoever the quantity of storage may be limited that is why the data has to be relayed with the technique already discussed

3.4 User's End

The passengers would automatically get notified when announcement will take place. If Wi-Fi is available with or without internet the system will work if Wi-Fi is not available then using an application the conversion will be done by accessing the microphone of the passenger’s device. The users would mainly be the cabin crew and passengers for whom an application is designed such that it is integrated with TensorFlow. The mobile application being designed is for the Android platform using Android Studio integrated with TF Speech. If internet connection is not established in the aircraft in that case the IFE system described in previous section shall kick-in providing the conversions over the Wi-Fi network. As shown in figure the app can be directly used by cabin attendants for making announcements by just texting into the network.

Figure 4 SKYVOIX User Interface

4. Methods

4.1 Deep Learning

Deep learning is a branch to artificial intelligence. Deep Learning algorithms have great potential for research into the automated extraction of complex data representations. Deep Learning algorithms can develop a layered, and hierarchical architecture of learning and representing data. Deep Learning in Big Data Analytics has become a high-focus of data science. A key benefit of Deep Learning is Big Data analysis that it can learn from massive amounts of unsupervised data. This makes it a valuable tool for Big Data Analytics where huge amounts of raw data are uncategorized. The internal working of the system is achieved by implementing the concept of deep learning which is closely related to machine learning and works upon neural network algorithms. The neural networks can be trained to
use encryptions such that no agent interferes into the network and can even limit the passenger’s internet surfing capabilities. The open source software library used for implementing this technique is TensorFlow that is used for practicing machine learning and evaluating large data sets.

1) Audio to text conversions
2) Real time mapping
3) Big Data Analytics:
   - ATC Data
   - On-Board Sensor and Recorder’s Data

A. Audio to text conversion

Deep learning for speech recognition is used with 5 CNN’s. It is also implemented with Tensorflow libraries. The training data is needed to be in batches with pilot and cabin commands in different emotions and are needed to be fed in to the neural network with learning rate as 0.0001 and weights are to be decided appropriately. All segments shall be classified independently. It is trained on the last layer of the Google’s Inception model.

![Figure 5 Inception Model Architecture](image)

Jianwei Niu in [5] used various features in their recognition system and combined DNN with HMM reporting 92.3% accuracy on 6 classes of 7676 spoken Mandarin Chinese sentences. H.M. Fayek in [6] explored various DNN architectures and reported accuracy around 60% on two different databases eNTERFACE [7] and SAVEE [8] with 6 and 7 classes respectively.

Sadly, we are not aware of any paper that used Deep Learning for Speech Emotion Recognition on Aircraft transmissions within and around.

B. Real Time Mapping and Big Data Analytics

Real time mapping is the automated flight planning of a localized airspace depending upon the traffic statistics achieved by feeding the airplane’s flight parameters like airspeed, heading, altitude, destination, approach and runway allotted into the deep learning powered processing unit. The flight parameters can be easily fed from the radar data. As this data is huge in quantity and is being updated
every second that is why it falls under the Big Data and thus its analysis in order to meet the required output is to guide the aircrafts safely abiding the airspace regulations. In this analysis Time Series Prediction is used. Big data is also used and processed for maintenance check which is determined by analyzing the sensor data in real time. This method is already used by commercial giant Etihad Airways to improve its economics and ergonomics. But this technique requires huge capital as big satellite bandwidth is required. Instead going by the satellite transmission altogether, the other method proposed is stored locally in the aircraft and relayed within wireless network between hub and devices and when required is down linked to ground or else near traffic such that a back up is created and accessed.

4.2 Error Control Codes

The error controlling coding is to be implemented to eliminate the redundancies in the communication channel and the converter so as to increase the accuracy. These codes implemented in deep learning framework are iterated many times to refine the result and in the end providing a desirable result. It works as Input data, pre-processing, neural networks, post process, output data. In the mentioned applications sometimes it happens that the data suffers from deficiencies which should be remedied before the data is used for network training. Convolution codes work on symbol streams of arbitrary length which are most often soft decoded with the Viterbi algorithm that comes under FEC Algorithms. When considering Hamming Code, the probability \( P(E) \) that the receiver commits an error is given by:

\[
P(E) = \frac{P_e}{P_c + P_e}
\]

Where \( P_e = (1 - p)^n \)

For (n,k) linear code:

\[
P_e \leq 2^{-n-k}[1 - (1-p)^n]
\]

5. Results

The converter based on Deep learning convolutional neural networks was implemented using TensorFlow. The trained model shall be incorporated with the mobile application SKYVOIX using TF Speech. The training is done on the last layer out of the 5 convolutional neural layers using the Inception model. The training shall be implemented using real training samples of the flight announcements following sampling processes. With this information training data set is generated and then it is trained at 15000 iterations and appropriate learning rate set at 0.001. The training is done in batches which mean that the input of samples to fit the model is defined. The discussed method is the ideal process which shall be implemented on a powerful machine with GPU Boosting. Instead the process was implemented at a small scale with the retraining process as shown with a training set of photographs classifying aircrafts which shall be implemented in ATC tracking in video feed with 4000 iterations achieving a final test accuracy of 78.4%.
The ATC traffic planning is done on the same deep learning platform, TensorFlow implementing Convolutional Neural Networks on the same Inception model used in the earlier case. The process for this would be the same but the training data would be different and would incorporate the data coming in from the radar namely present coordinates, altitude and magnitude.

The physical layouts as discussed earlier are compatible with the current IFE Systems like that of Thales IFE. As the layout has independent circuitry it does not hinder in the present system. It just draws the input from the sources that can be done by adding an extra node maintaining the transfer function. The power requirement should be 28VDC that is a standard for the aircraft instruments.

6. Conclusion and Discussions

The question of how to improve the avionics for the modern and busy skies has been a popular research topic. This study proposed an effective method to improve the current technology with the help of data sciences which makes the proposed system intelligent such that the processes are automated and accurate that lays down the framework for increasing the safety in skies. Deep Learning is used for the same which is a sub-division of artificial intelligence. The implementation of Big Data and Deep Learning goes hand in hand. Its application includes Remote Sensing Data from satellites and being used for Image and object based classification which can also be implemented using TensorFlow API. Compared to traditional classification methods, the proposed model shall be able to do speech recognition in addition to voice recognition and converts it. The Deep Neural Networks makes processing becomes fast, in-depth replicating the functions of human brain. The module proposed for passengers is as important as communicating to ATC. The main aim for aviation is to improve transferability without compromising safety but today’s scenario is the complete faith of passengers in the technology being totally ignorant. The device application should be able to monitor over that aspect making a richer user interface. The concept of Big Data and deep learning is to be applied for the aircraft monitoring as well data synthesis with minimum data loss and better compressibility which shall determine the feasibility of the system. A significant move to intelligent
systems may make the sky easier for travelling in days to come and even maintain considerable low load factor on the traffic controller and pilots reducing the Human Error.

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