CHAPTER - 6

EXPERIMENTAL ANALYSIS

6.1 INTRODUCTION

In this chapter, the difference between the actual existing system and our proposed system is analyzed. The prominent feature of this analysis is, it describes the real advantage of our proposed system and the disadvantage of existing system. With the help of this analysis the impact of stress faced by the air traffic controllers and the importance of automating air traffic control is inferred. This chapter also describes the analysis of different modules and concepts used for arriving solution. Analyzing involves, understanding the purpose of the analysis and what causes the required results. This project focuses on the analysis of automating approach and clearance in air traffic system and analyses the usage of LSTM over other concepts. The proposed system uses Long Short Term Memory for the summarization part and uses pandas for retrieving data for generating response.

6.2 ANALYSIS OF EXISTING AIR TRAFFIC CONTROL SYSTEM

An Air Traffic Control (ATC) network consists of departure airports, a single landing airport and a network of airways connecting the airports. The flights planned to be carried over the network represent the demand for service which should be served during a given period of time under given conditions. Landing airport capacity is the element of the network which causes congestion and potentially lengthy flight delays which spread over the network. Under such conditions the landing airport and the ATC network are considered to be overloaded.

The primary purpose of Air Traffic Control (ATC) is to ensure that aircraft to their destination in a safe, orderly and expeditious manner. Demand on airspace has increased over the years and ATC has had to adapt in order to maintain a safe and efficient service. Traditionally Controllers have sequenced arrivals First-Come-First-Serve (FCFS). However, sequencing aircraft in a different order may help minimize delay or maximize use of runway. Air traffic control is a highly demanding job which requires high levels of responsibility with inherent stress due to its nature and the complexity of tasks involved. Just like the flight crews who work in an intensive, stressful environment, air traffic controllers are considered the aviation professionals who face very high levels of stress.

Air traffic control in its nature entails a complex set of tasks demanding levels of knowledge and expertise, as well as the practical application of specific skills pertaining to:

- the cognitive domain (e.g. spatial perception, information processing, movement detection, image and pattern recognition, prioritization, logic reasoning and decision making),
- communicative aspects (verbal filtering including phraseology and language clarity), and
- Human relations (teamwork and communication strategies).

The air traffic controller must constantly re-organize and adapt his or her system of processing information (often done under time deficit) by changing operating methods (in particular, cognitive processes, conversation, coordinating with other controllers, assistants, anticipation and solving problems) as they arise and interact with each other. This is carried out by means of the precise and effective application of rules and procedures that need to be quickly selected and applied according to differing circumstances. It is evident that the job entails, on the whole, high psychological demands while being subjected to a considerable degree of external control.

6.3 ANALYSIS OF STRESS FACTOR IN EXISITNG SYSTEM

The most common sources of stress reported by air traffic controllers are connected with both operational aspects and internal organizational structures. Sources of stress related to the operational aspects (list not intended to be comprehensive):

- Peaks of traffic load
- Time deficit
- Operational procedures (often limited and need to be adapted)
- Limitation and reliability of equipment
- Abnormal/Emergency Situations

Sources of stress related to organizational aspects (not comprehensive):

- Shift schedules (night work in particular)
- Management
- Role conflicts
- Unfavorable working conditions

These stress factors, related to both aspects, can affect the job satisfaction and the general health of air traffic controllers. In fact, as the workload increases the air traffic controller tends to employ more procedures which are less time-consuming, together with a progressive reduction to the minimum of flight information and the relaxation of certain self-imposed qualitative criteria. It is evident that the number of decisions to be made becomes a stressful condition when the controller’s decision-making capacity is stretched to the maximum; this can lead, in case of overload, to a very risky situation often addressed as a “loss of the picture”. In addition, it is frequently reported that, many errors often occur during periods of light and non-complex traffic. This point highlights the need of extra effort required to regulate the psycho-physical reactions, maintaining a high level of arousal and vigilance even in conditions of "light traffic load". Fig 6.1 represents structure of ATC human errors mainly caused by stress factor.

Category	Explanation	Elements	Operational definition
Communication error	Difficulties in communicative interaction or aeronautical operations	C1	Incorrect Readback Not challenged
		C2	Wrong callsign Used
		C3	Non-standard Phraseology
		C4	Missed call
		C5	Callsign Omission/Truncation
		C6	Clipped call
Procedure error	Errors such as difficulties in following checklists	P1	Failure to respond to unanswered call
		P2	No/late response to alarm
		P3	No level verification
		P4	No Identification of aircraft
		P5	Radar service not terminated
		P6	Late/No Issuance of landing clearance
		P7	Reasons for Vectoring not Given
Instruction error	Errors such as giving incorrect instructions	I1	Incorrect information passed to aircraft
		I2	Late descent
		I3	Late change
		I4	Altitude Instruction Error
		I5	Heading Instruction Error
		I6	Clearance Instruction Error

Fig 6.1 structure of ATC human errors mainly caused by stress factor.

Courtesy: Air traffic volume and human control errors.pdf

Fig 6.2 represents error frequency by levels of air traffic volume.

Air traffic volume (V^*)	Error Type	Minimum frequency	Maximum frequency	Average frequency	Standard deviation
V1	Commu-nication error	0	4	1.75	1.26
V2		1	5	2.73	1.19
V3		0	6	3.28	1.97
V1	Proce-dure error	0	5	1.51	1.05
V2		1	8	3.23	1.72
V3		1	10	5.00	2.24
V1	Instruc-tion error	0	2	0.42	0.72
V2		0	5	1.59	1.53
V3		0	6	2.34	1.78

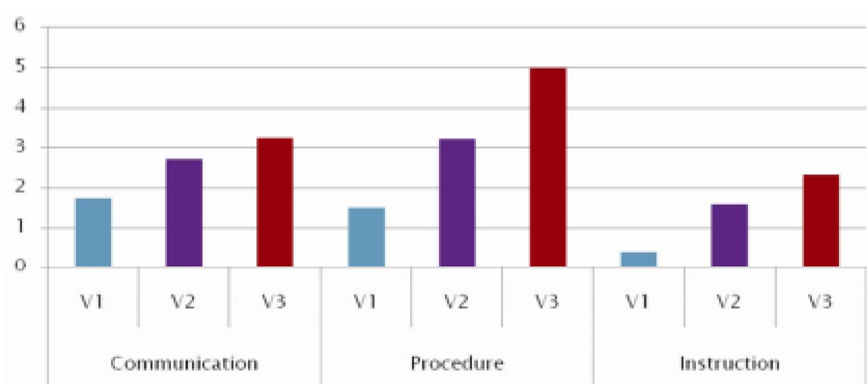

Fig 6.2 error frequency by levels of air traffic volume.

Courtesy: Air traffic volume and human control errors.pdf

6.3 ANALYSIS OF PROPOSED SYSTEM

The accident rate caused by ATC errors are not so high. But even though it's low, it results in severe causalities. In order to avoid this, we propose a new system. The proposed system is mainly a solution to eliminate the occurrence of human errors due to physical and mental stress. The system is implemented by modularizing it into 5 parts depending on its working. The factors considered for making these 5 modules were the entities involved in a conversation between a pilot and a controller. The entities are: Pilot, who requests controller for landing/takeoff – approach/clearance, our controller bot, and a human controller who supervises the working of bot. All the 5 modules comes under 3 sub-divisions: Data Collection, Data Pre-processing and Data Analysis. Module 1 is also given a name "Pilot request speech to text" where the pilot entity and controller bot are involved. Module 2 is named "Text Summarization" which is a vital part of Controller bot and accomplished by implementing LSTM. Module 3 is named "Response Generation" which also involves stop words removal in it. Module 4 is the last module which is "Text to Pilot response" which also includes a sub-module called "Flight information inclusion", where controller bot sends response to pilot's request.

6.4 MODULE ANALYSIS

The analysis is done in every module to check the proposed system is working properly. The overall function of the proposed system is analyzed. In our proposed system, we implemented the system in four modules. The modules included in our system are Speech to text, Text Summarization, response Generation, Text to speech.

6.4.1 MODULE 1 - SPEECH TO TEXT ANALYSIS

One of the greatest hurdles for introducing higher levels of automation in air traffic management (ATM) is the intensive use of voice radio communication to convey air traffic control (ATC) instructions to pilots. Automatic speech recognition, which converts human speech into texts, can provide a solution to significantly reduce controllers' workloads and increases air traffic management efficiently. The first module of our system converts the pilot's request speech to text. This module can also be called as Speech recognition module. This is a vital task which takes place initially in the entire process. This module comes under Data collection because, we collect the data from pilot's request. The pilot's request is collected as audio file in wav format or it is directly obtained through hardware microphones. Then the collected audio file is converted to text, by including google speech to text package in the source code and relevant text is obtained. This is done so, in order to understand the pilot's need and intentions. As our system is a chat bot kind of controlling system, it needs to understand the vocabulary and content in the pilot's request properly. So pilot's speech is converted to text. But during this process, noise is a concerning factor. The reason is, it may even change the context of the request from pilot, and confuses the system. So noise factor has to be considered.

Currently, several speech recognition modules require a manual adaptation to local needs caused by acoustic and language variabilities such as regional accents, phraseology deviations and local constraints. So different languages and accent are not considered as this is just a beginning of new system. So we consider common English and its standard accent. We initially pass an audio file as pilot's request in standard wav format to obtain text.

6.4.2 MODULE 2 – TEXT SUMMARIZATION ANALYSIS

The module 2 of our system is "Text Summarization". This comes under data collection and data pre-processing. This step initially gets the converted text as input. Here in this step we remove or prune unnecessary words in the statement, that a search engine has been programmed to ignore, both when indexing entries for searching and when retrieving them as the result of a search query are called as 'stop words' and we take only the keywords, which are termed as 'tokens'.

LSTM text summarization is performed here. Thus the process of converting data into something a computer can understand and pre-processing only the required content (keywords) and removing the unwanted data (stop words) is known as ‘data preprocessing’. Then the keywords are collectively stored and made used for further steps.

The reason behind the importance of this second module is, we generally need to know the pilot’s need just by understanding his request. So in order to make our system understand the pilot’s needs, we remove stop words first and collect only the key words. Each and every keyword in pilot - controller conversation possess specific set of meanings. So tokenizing and processing keywords play an important role in our system.

6.4.3 MODULE 3 – ANALYSIS OF RESPONSE GENERATION

The most important process takes place in this 3rd module. This is an important stage, where the system is going to generate response to the pilot, that’s why its name is “Response Generation” module. Here the keywords generated from the previous module 2 are obtained. Then it undergoes comparison phase, where the keyword(s) get compared with the keywords in a csv (comma separated values) file where corresponding responses are already fed into it.

Here we compare that one generated keyword with the set of keywords in the csv file. After comparing, it generates the response for corresponding request keyword. To access CSV file contents and to perform operations in it, we use ‘pandas’ (panel-data) library to retrieve the corresponding response data from the file and from the keyword obtained from the previous module, we thereby generate suitable response. Moreover we use ‘pandas’ library for data manipulation and analysis. It takes keyword as input request and after the comparison phase it generates the full response text. For instance it takes AI101 (flight number) and “requesting for take-off” and it generates “Cleared for takeoff” which is a partial response to the pilot. Likewise the conversation between an air traffic controller and pilot is vast. But we have chosen a specific set of basic and default conversation between them. The system generates responses for landing/take-off approach/clearance requests alone.

6.4.3.1 SUB MODULE 1 – FLIGHT INFORMATION INCLUSION

This sub-module is named “Flight information inclusion”. The main use of this sub-module is to add flight details alongside the response command that is generated in the previous main-module. The reason for adding flight details is to identify their own responses for pilots as, not only one aircraft is going to use the aerodrome for takeoff/landing. The controller has to manoeuvre many aircrafts. So while responding, they use the flight number of that aircraft with their response, sometimes from/to aerodrome also. We retrieve the flight details, in the beginning itself and add additional details, along with the response.

Flight information is obtained from flight plan that is given by respective pilots to controllers that holds all the vital information about the aircrafts which includes flight name, number, variant, from/to aerodrome etc. Every aircraft will hold its own unique detail of the day. So retrieving the flight detail (aircraft number) is important. Flight detail is retrieved from CSV file. We create a flight plan model and store it in a file. So when the pilot requests, they will surely mention the aircraft ID (flight number) which is a mandatory rule. This flight number is retrieved from that request initially after data pre-processing stage. Then the flight number is compared with the data in the flight plan model. After comparing, flight the necessary flight details are obtained.

The obtained flight details are stored and after processing of other details, such as response generation, all these details are added or appended or concatenated with the response and proper response is generated for the pilot’s response.

6.4.4 MODULE 4 – TEXT TO SPEECH ANALYSIS

The last and final module of the process is “Text to Pilot response” module. After successful completion of obtaining response text for pilot’s request by executing all these above modules, it has to be converted to speech (audio) format. After generating audio response, it has to be sent to the pilot, who waits for response from controller. The request-response conversation has to be quick and spontaneous.

6.5 ANALYSIS OF LSTM

The main reason for preferring LSTM over the other concepts, is its memory. LSTM stands for Long Short-Term Memory (LSTM), which is an artificial recurrent neural network (RNN) architecture used in the field of deep learning. The main reason for preferring LSTM over other is, LSTM networks are well-suited to classifying, processing and making predictions based on time series data, since there can be lags of unknown duration between important events in a time series. In our system, Input data (text) go into the nodes of the input layers and the information is combined in a weighted manner and passed onto the next layer and so on, until it comes out of the output layer. Now the expected output (summarized form) is obtained. This comes under data collection and data pre-processing. This step initially gets the converted text as input. Here in this step we remove or prune unnecessary words in the statement, that a search engine has been programmed to ignore, both when indexing entries for searching and when retrieving them as the result of a search query are called as ‘stop words’ and we take only the keywords, which are termed as ‘tokens’.

LSTM text summarization is performed in our system. Thus the process of converting data into something a computer can understand and pre-processing only the required content (keywords) and removing the unwanted data (stop words) is known as ‘data preprocessing’. Then the keywords are collectively stored and made used for further steps. The reason behind the importance of this second module is, we generally need to know the pilot’s need just by understanding his request. So in order to make our system understand the pilot’s needs, we remove stop words first and collect only the key words. Each and every keyword in pilot - controller conversation possess specific set of meanings. So tokenizing and processing keywords play an important role in our system.

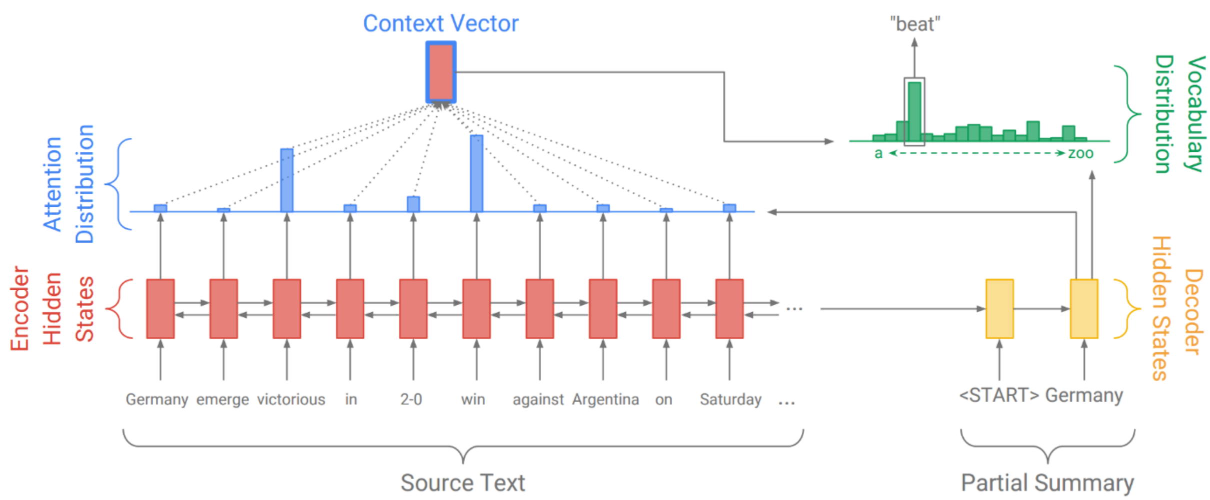

Fig 6.3 Text summarization using deep learning

Fig 6.3 represents text summarization using deep learning. LSTM is great tool for anything that has a sequence. Since the meaning of a word depends on the ones that preceded it. This paved the way for NLP and narrative analysis to leverage Neural Networks. LSTM can be used for text generation. You can train the model on the text of a writer, say, and the model will be able to generate new sentences that mimics the style and interests of the writer. The main reason for preferring LSTM over the other concepts, is its memory, well-suited to classifying, processing and making predictions based on time series data, since there can be lags of unknown duration between important events in a time series.

6.6 SUMMARY

In this chapter, the difference between the actual existing system and our proposed system has been analyzed. By doing this analysis, the features pf our proposed system is well understood along with its modules, and its advantages over the existing system is proven. With the help of this analysis the impact of stress faced by the air traffic controllers and the importance of automating air traffic control is understood. This chapter also describes the analysis of different modules and concepts used for arriving solution. The analysis of automating approach and clearance in air traffic system and the usage of LSTM over other concepts has been focused. The proposed system uses Long Short Term Memory for the summarization part and uses pandas for retrieving data for generating response. The Objective of this work is to develop an automated environment for Air Traffic Services, by implementing a new concept in RNN called LSTM. Air Traffic Control is a tedious task and automating such task is a challenging one. Because of this, the stress faced by the controllers will be considerably reduced. Our project intends to create an automated tool that process, analyses the output according to the input from the pilots. Thus this system will be great boon for controllers.