A NLP INTEGRATED APPROACH FOR CLEARANCE CONTROL IN AIR TRAFFIC SERVICES

A PROJECT REPORT

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BONAFIDE CERTIFICATE

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ABSTRACT

Air Traffic Control (ATC) is one of the most important part in aviation. Air Traffic Controllers, sometimes referred as ATCOs, are the guardian angles of the sky. They are provided by means of ground-based traffic controllers, who directs the plane through the managed airspace, and offers consultative services to plane in non-controlled airspace. The first motive of ATC global is to prevent collisions, organize and expedite the glide of traffic, and furnish facts and different aid for pilots. Air traffic management is one in all the foremost stressful job because it needs high level human intervention, concentration and dynamic deciding. Therefore ATC is that the least automatic field in aviation because of challenges faced in voice recognition and transmission. Our plan primarily uses decision sign detection and text to speech conversion by implementing LSTM to instruct the pilot for handling the flight. The LSTM model is fed with inputs from the pilot and undergoes text summarization part. The main downside is going to be, hissing channel, that ends up in poor voice recognition. Our project uses long short term memory of perennial neural networks for text connected process of knowledge and conjointly aims in building a good voice recognition server.

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CHAPTER – 1

INTRODUCTION

Aviation comes from the Latin word meaning "bird," an appropriate translation given that aviation deals with travel by air, specifically in a plane. The aviation industry is the business sector dedicated to manufacturing and operating all types of aircraft. Aviation safety means the state of an aviation system or organization in which risks associated with aviation activities, related to, or in direct support of the operation of aircraft, are reduced and controlled to an acceptable level. It encompasses the theory, practice, investigation, and categorization of flight failures, and the prevention of such failures through regulation, education, and training. It can also be applied in the context of campaigns that inform the public as to the safety of air travel. Air Traffic Control which is popularly known as “ATC”, is a communication-based method through which the pilots in the air are given proper instructions and commands in controlled airspace to safely manoeuvre the aircraft from any dangerous situation and land the aircraft safely in an orderly fashion. Not only on the air but even on the ground it is the Air Traffic Controller’s responsibility to guide to the aircraft through the airport to the runway if it’s a departing aircraft and to the parking bay if it has just arrived. The ground based controller must accomplish two main tasks. The first task is to ensure all aircrafts are safe. The second task is to provide information to pilots. Air Traffic Controllers, who maintain the flow of aircraft in and out of airports and in flight, are key to aviation safety. So this is well recognized as one of the most stressful jobs, requiring total concentration. Radar controllers, as opposed to tower controllers, also have to work in semi-darkness with an airplane full of passengers in their sight as a mere luminous blip on the screen. The 24/7 staffing of the Air Traffic system sometimes requires more than 40 hour days including nights and weekends. This creates physical as well as mental stress and results in human-errors. So Air Traffic Control ranks’ 4th in the all-time most stressful jobs in the world by Bureau of Labor Statistics. So our goal is to automate a part of Air Traffic Services which is Approach and Clearance Control considering the normal or usual conditions alone.

1.1 INTRODUCTION TO AIR TRAFFIC CONTROL

Air traffic control (ATC) is a service provided by ground-based air traffic controllers who direct aircraft on the ground and through controlled airspace, and can provide advisory services to aircraft in non-controlled airspace. The primary purpose of ATC worldwide is to prevent collisions, organize and expedite the flow of air traffic, and provide information and other support for pilots. In some countries, ATC plays a security or defensive role, or is operated by the military.

Air traffic controllers monitor the location of aircraft in their assigned air space by radar and communicate with the pilots by radio. To prevent collisions, ATC enforces traffic separation rules, which ensure each aircraft maintains a minimum amount of empty space around it at all times. In many countries, ATC provides services to all private, military, and commercial aircraft operating within its airspace. Depending on the type of flight and the class of airspace, ATC may issue instructions that pilots are required to obey, or advisories (known as flight information in some countries) that pilots may, at their discretion, disregard. The pilot in command is the final authority for the safe operation of the aircraft and may, in an emergency, deviate from ATC instructions to the extent required to maintain safe operation of their aircraft.

1.1.1 AIRPORT TRAFFIC CONTROL TOWER

The primary method of controlling the immediate airport environment is visual observation from the airport control tower. The tower is a tall, windowed structure located on the airport grounds. Air traffic controllers are responsible for the separation and efficient movement of aircraft and vehicles operating on the taxiways and runways of the airport itself, and aircraft in the air near the airport, generally 5 to 10 nautical miles (9 to 18 km) depending on the airport procedures.

Surveillance displays are also available to controllers at larger airports to assist with controlling air traffic. Controllers may use a radar system called secondary surveillance radar for airborne traffic approaching and departing. These displays include a map of the area, the position of various aircraft, and data tags that include aircraft identification, speed, altitude, and other information described in local procedures. In adverse weather conditions the tower controllers may also use surface movement radar (SMR), surface movement guidance and control systems (SMGCS) or advanced SMGCS to control traffic on the maneuvering area (taxiways and runway).

The areas of responsibility for tower controllers fall into three general operational disciplines: local control or air control, ground control, and flight data or clearance delivery—other categories, such as Apron control or ground movement planner, may exist at extremely busy airports. Remote and virtual tower (RVT) is a system based on air traffic controllers being located somewhere other than at the local airport tower and still able to provide air traffic control services. The complex structure comprises an elongated ground building for administration and technology, a 70m tower shaft and a flight station for the controllers – a 16-corner polygon on an elliptical floor plan in the pinnacle of the tower shaft. Two boxes, suspended from the tower shaft, accommodate server rooms, staff rooms and a crisis room. The new ATC Tower at Heathrow is a new prominent feature at the airport. The tower was designed by the Richard Rogers Partnership and engineered by Arup. The tower reached an important stage at the end of 2005 with a topping-out ceremony when its full height of 87m (285ft) was achieved. The topping-out ceremony involved gold bolts being tightened ceremoniously at the base of the tower to mark the completion of the main structure. The new tower is more than twice the height of the old tower and will offer better unobstructed 360° views of the airport for controllers. Fig 1.1 shows Air Traffic Control tower of London Heathrow Airport and Fig 1.2 shows tower interior.

Fig 1.1 London Heathrow Airport ATC Tower.

Courtesy: pinterest.com

Fig 1.2 ATC tower Interior.

Courtesy: boldmethod.com

1.1.2 GROUND CONTROL

Ground control (sometimes known as ground movement control) is responsible for the airport "movement" areas, as well as areas not released to the airlines or other users. This generally includes all taxiways, inactive runways, holding areas, and some transitional aprons or intersections where aircraft arrive, having vacated the runway or departure gate. Exact areas and control responsibilities are clearly defined in local documents and agreements at each airport. Any aircraft, vehicle, or person walking or working in these areas is required to have clearance from ground control. This is normally done via VHF/UHF radio, but there may be special cases where other procedures are used. Aircraft or vehicles without radios must respond to ATC instructions via aviation light signals or else be led by vehicles with radios. People working on the airport surface normally have a communications link through which they can communicate with ground control, commonly either by handheld radio or even cell phone. Ground control is vital to the smooth operation of the airport, because this position impacts the sequencing of departure aircraft, affecting the safety and efficiency of the airport's operation. Fig 1.3 shows ground control staffs.

Fig 1.3 Ground Control staffs

Courtesy: internationalairportereview.com

1.1.3 AIR CONTROL OR LOCAL CONTROL

Air control (known to pilots as "tower" or "tower control") is responsible for the active runway surfaces. Air control clears aircraft for takeoff or landing, ensuring that prescribed runway separation will exist at all times. If the air controller detects any unsafe conditions, a landing aircraft may be instructed to "go-around" and be re-sequenced into the landing pattern. This re-sequencing will depend on the type of flight and may be handled by the air controller, approach or terminal area controller.

Within the tower, a highly disciplined communications process between air control and ground control is an absolute necessity. Air control must ensure that ground control is aware of any operations that will impact the taxiways, and work with the approach radar controllers to create "gaps" in the arrival traffic to allow taxiing traffic to cross runways and to allow departing aircraft to take off. Ground control need to keep the air controllers aware of the traffic flow towards their runways in order to maximize runway utilization through effective approach spacing. Crew resource management (CRM) procedures are often used to ensure this communication process is efficient and clear. Within ATC, it is usually known as TRM (Team Resource Management) and the level of focus on TRM varies within different ATC organizations.

1.1.4 APPROACH AND TERMINAL CONTROL

Many airports have a radar control facility that is associated with the airport. In most countries, this is referred to as terminal control; in the U.S., it is referred to as a TRACON (terminal radar approach control). While every airport varies, terminal controllers usually handle traffic in a 30-to-50-nautical-mile (56 to 93 km) radius from the airport. Where there are many busy airports close together, one consolidated terminal control center may service all the airports. The airspace boundaries and altitudes assigned to a terminal control center, which vary widely from airport to airport, are based on factors such as traffic flows, neighboring airports and terrain. A large and complex example was the London Terminal Control Centre, which controlled traffic for five main London airports up to 20,000 feet (6,100 m) and out to 100 nautical miles (190 km).

Terminal controllers are responsible for providing all ATC services within their airspace. Traffic flow is broadly divided into departures, arrivals, and overflights. As aircraft move in and out of the terminal airspace, they are handed off to the next appropriate control facility (a control tower, an en-route control facility, or a bordering terminal or approach control). Terminal control is responsible for ensuring that aircraft are at an appropriate altitude when they are handed off, and that aircraft arrive at a suitable rate for landing. Fig 1.4 shows Approach and Terminal control room.

Fig 1.4 Approach and Terminal Control room.

Courtesy: airport-technology.com

1.1.5 AREA OR CENTER CONTROL

ATC provides services to aircraft in flight between airports as well. Pilots fly under one of two sets of rules for separation: visual flight rules (VFR) or instrument flight rules (IFR). Air traffic controllers have different responsibilities to aircraft operating under the different sets of rules. While IFR flights are under positive control, in the US and Canada VFR pilots can request flight following, which provides traffic advisory services on a time permitting basis and may also provide assistance in avoiding areas of weather and flight restrictions, as well as allowing pilots into the ATC system prior to the need to a clearance into certain airspace. Across Europe, pilots may request for a "Flight Information Service", which is similar to flight following. In the UK it is known as a "basic service". En-route air traffic controllers issue clearances and instructions for airborne aircraft, and pilots are required to comply with these instructions. En-route controllers also provide air traffic control services to many smaller airports around the country, including clearance off of the ground and clearance for approach to an airport. Controllers adhere to a set of separation standards that define the minimum distance allowed between aircraft. These distances vary depending on the equipment and procedures used in providing ATC services. Fig 1.5 shows Area Control room.

Fig 1.5 Area Control

Courtesy: Areacontrolcentre.com

1.1.6 RADAR COVERAGE

Since centers control a large airspace area, they will typically use long range radar that has the capability, at higher altitudes, to see aircraft within 200 nautical miles (370 km) of the radar antenna. They may also use TRACON radar data to control when it provides a better "picture" of the traffic or when it can fill in a portion of the area not covered by the long range radar. In the U.S. system, at higher altitudes, over 90% of the U.S. airspace is covered by radar and often by multiple radar systems; however, coverage may be inconsistent at lower altitudes used by unpressurized aircraft due to high terrain or distance from radar facilities. A center may require numerous radar systems to cover the airspace assigned to them, and may also rely on pilot position reports from aircraft flying below the floor of radar coverage. This results in a large amount of data being available to the controller. To address this, automation systems have been designed that consolidate the radar data for the controller. This consolidation includes eliminating duplicate radar returns, ensuring the best radar for each geographical area is providing the data, and displaying the data in an effective format.

Some air navigation service providers (e.g., Air services Australia, the U.S. Federal Aviation Administration, NavCanada, etc.) have implemented automatic dependent surveillance – broadcast (ADS-B) as part of their surveillance capability. This new technology reverses the radar concept. Instead of radar "finding" a target by interrogating the transponder, the ADS-equipped aircraft sends a position report as determined by the navigation equipment on board the aircraft. Normally, ADS operates in the "contract" mode where the aircraft reports a position, automatically or initiated by the pilot, based on a predetermined time interval. It is also possible for controllers to request more frequent reports to more quickly establish aircraft position for specific reasons. However, since the cost for each report is charged by the ADS service providers to the company operating the aircraft, more frequent reports are not commonly requested except in emergency situations. ADS is significant because it can be used where it is not possible to locate the infrastructure for a radar system (e.g., over water). Computerized radar displays are now being designed to accept ADS inputs as part of the display. This technology is currently used in portions of the North Atlantic and the Pacific by a variety of states who share responsibility for the control of this airspace.

1.2 INTRODUCTION TO DATA MINING IN AVIATION (AIR TRANSPORT MANAGEMENT)

Data mining techniques are used to identify patterns and anomalies in Air Traffic Control Operational Errors (OEs). The reduction of Operational Errors plays an important role and remains a challenge in the aviation safety community. Traditional methods focuses on individual aspects of OEs, are limited to operations at a single facility. An attribute focusing technique is applied to study 15 years of operational errors at all FAA Air Route Traffic Control Centers (ARTCCs) 1 in the National Airspace System (NAS) in the U.S. to find 'interesting' patterns of common characteristics, anomalies, and changes in trends of operational errors. NASA has created tools to discover interesting patterns in large data sets in order to ensure its techniques can make a real impact on flight safety and efficiency to make things more accurate or user friendly. Southwest Airlines (fig 1.6) uses reported information to identify and communicate certain issues to Air Traffic Controllers, making them aware, for example, of how certain instructions impacted an airplane’s operations. By collaborating with them, Southwest has since seen a steady improvement in the quality of approaches. Like many airlines, Southwest has traditionally looked for performance issues in its data using exceedances checked against a model. During arrival, for instance, the plane might record an exceedance if it is travelling faster than 250 knots while its altitude is less than 10,000 feet.

Fig 1.6 Southwest Airlines B737

Courtesy: jetphotos.com

NASA's algorithms used by Southwest are the Multivariate Time Series (MTS) search and Virtual Sensors which are used in "letting the data speak for itself by finding unusual flights and candidate anomalies, without having any preconceived notion of what is normal or abnormal. But sometimes you find statistical anomalies that are not safety concerns, but the benefit is that sometimes you'll find anomalies that turns out to be safety concerns or have other operational significance, such as excessive fuel use. These algorithms helped Southwest Airlines to identify areas of concern in certain flight data. By working with its pilots and Air Traffic Control, the company has since seen an increase in the number of stable approaches by its aircraft. Like many airlines, Southwest has traditionally looked for performance issues in its data using exceedances checked against a model. During arrival, for instance, the plane might record an exceedance if it is travelling faster than 250 knots while its altitude is less than 10,000 feet. Each morning, the company looks at a report of all the exceedances that took place the previous day and decides what action to take in the case of undesirable trends. By making use of data mining tools, Southwest can now query the data itself to figure out what normal operations really look like, thus making an impact on commercial flight safety.

1.2.1 DATA MINING IN AIR TRAFFIC FLOW FORCASTING

The Air Traffic flow prediction plays a key role in the airspace simulation model and Air Traffic flow management system. In China the Air Traffic information in each regional control center has not integrated together by now. Large collection of radar data is stored. But there is no effort made to extract useful information from the database to help in the estimation. Data mining is the process of extracting patterns as well as predicting previously unknown trends from large quantities of data. Neural network and statistics are frequently applied to data mining with various objectives. Here neural networks is combined with the statistical analysis of historical data to forecast the traffic flow. Two models with different types and input data are proposed. The accuracy of two models is tested and compared to each other using flow data at an arrival fix in Beijing control center. The result shows that these models are feasible for practical implementations. The suitable models for different prediction conditions are also suggested.

Many study centers has developed a model for the purpose of Air Traffic forecasting by using off-the-shelf data mining and machine learning techniques. Recent developments use data mining algorithms to predict the likelihood of previously un-connected airport-pairs being connected in the future, and the likelihood of connected airport-pairs becoming un-connected. Despite the innovation of this research, it does not focus on improving the FAA’s existing methodology for forecasting future Air Traffic levels on existing routes, which is based on relatively simple regression and growth models. So different approaches are investigated for improving and developing new features within the existing data mining applications in Air Traffic forecasting. As part of future work, machine learning techniques such as clustering and neural networks are getting applied to improve this model's performance.

1.2.2 DATA MINING IN AIR TRAFFIC FLOW MANAGEMENT AND ANALYSIS FOR INFLIGHT COST OPTIMIZATION

The Air Traffic volume has increased significantly over the world. So the great mass of traffic management data, named as Big Data, have also accumulated day by day. This factor presents more opportunities and also challenges as well in the study and development of Air Traffic Management (ATM). Usually, Decision Support Systems (DSS) are developed to improve the efficiency of ATM. Bayesian network approach is used for the data analysis to reduce the costs of flight delay. The process makes possible to adjust the flight plan such as the schedule of arrival at or departure from an airport and also checks the airspace control measurements considering weather conditions. An experimental study is conducted based on the flight scenarios between Los Angeles International Airport (LAX) and Miami International Airport (MIA).

1.2.3 DATA MINING METHODS TO INCREASE THE SAFETY AND REDUCE THE NEGATIVE ENVIRONMENTAL IMPACTS IN AVIATION

The Single Europe Sky Air Traffic Management Research (SESAR) program developed and implemented innovative technological and operational solutions to modernize European Air Traffic management and to eliminate the negative environmental impacts of aviation activity. This SESAR Solution aims to mitigate the risk of runway excursion, to optimize airport operation management by decreasing the number of runway inspections, to make chemical treatment effective with respect to the environment, and to increase resilience, efficiency and safety in adverse weather situations. This approach is based on the enhancement of runway surface condition awareness by integrating data from various sources. Dangerous windy conditions based on Lidar measurements are also discussed as another relevant factor in relation to runway excursions. Four different data mining methods are explored to obtain runway conditions from the available input data sources, examines their performance and discusses their pros and cons in comparison with a rule-based algorithm approach. The output of the SESAR Solution is developed in compliance with the new Global Reporting Format of the International Civil Aviation Organization for runway condition description to be valid from 2020. This standard is expected to provide concerned stakeholders with more precise information to enhance flight safety and environmental protection.

1.3 RESPONSIBILITES OF AN AIR TRAFFIC CONTROLLER

- Coordinate the movement of air traffic to ensure that planes stay safe distances apart.
- Coordinate the arrival and departure of airplanes.
- Issue landing and takeoff instructions to pilots.
- Monitor and direct the movement of aircraft, using radar equipment.
- Authorize flight path changes.
- Provide weather updates to pilots.
- Alert airport response staff in the event of an aircraft emergency.
- Direct planes efficiently to minimize delays.
- Manage the flow of airplanes in and out of the airport.
- Guide pilots during takeoff and landing.
- Monitor airplanes as they travel through the skies.
- Check flight plans, give pilots clearance for takeoff or landing
- Direct the movement of planes on the runways and other parts of the airport.

- Sequence the arrival and departure of airplanes, and use radar equipment to monitor flight paths.
- Provide pilots with information on weather conditions.
- Monitor airplanes once they leave an airport's airspace.
- Look for traffic patterns that could create bottlenecks in the system.
- Keep traffic levels manageable for the airport and for en route controllers.
- Move all aircraft safely and efficiently through their assigned sector of airspace.
- Communicate with the pilots of aircraft using a push-to-talk radiotelephony system.
- Control aircraft within the immediate vicinity of the airport and use visual observation from the airport tower.

1.4 PROBLEMS IN AIR TRAFFIC CONTROL

With the rise in the airline industry and construction of new airports and runways, air traffic has increased dramatically in the past few years. It has put additional pressure on air traffic control system that handles thousands of flights per day. To avoid delays and collisions, air traffic management has to work efficiently. Many problems and challenges are faced by them. Some of the major problems faced by controllers are:

- Communication
- Weather
- Frequency Congestion
- Work
- Noise

The above problems are briefly described below.

- **Communication**

Air traffic controllers constantly need to intently listen to every single word said by pilots and other controllers. They need to be aware that what is going on in their space as well as other sectors around them. If a problem arises, they need to act on it at the very moment. It puts a lot of pressure on air traffic controllers.

- **Weather**

Another biggest issue for a controller is the weather. It adversely affects the work and function of air traffic control staffs. The more it is complex; the more workload is laden on them. A bad weather means a bad day for them.

- **Frequency Congestion**

Often simple things may turn complicated when there are too many persons are speaking on one frequency at a time. Each frequency can support only one person talking at a time, means either pilot or controller. A controller needs to master the flow of communication on that frequency.

- **Work**

If an air traffic control is managing 50,000 flights daily; they have to handle many flights at the same time. It means checking the altitude so that they don’t collide against. Plus, multiple flights pass in the same route and during such situation if a flight face problem, they need to give special attention. However, the bigger problems occur when a passenger aircraft goes missing the radar range, or the radar of air traffic control goes down.

- **Noise**

Aircraft noise and its impact on local communities is also a major problem that needs attention. In the upcoming years, with the rise in aircraft numbers, this issue is only going to trigger. It needs to make a balance between the needs of a country and managing the impact on local communities who are living close to airports.

1.5 ATC ERROR CATEGORIES

Based on many interviews, study, research and surveys of ATC safety experts, the ATC errors are categorized into three major categories. They are communication error, procedure error, and instruction error. The definition of each error category is as follows:

- **Communication Errors**

This refers to errors during radio communication. Communication error in ATC is divided into the two categories of errors that occur between a pilot and an air traffic controller, and the errors that occur between air traffic controllers. For instance, there are errors such as not challenging incorrect read back, using wrong call-signs, using non-standard phraseology, and missing and clipping the call sign.

- **Procedure Errors**

This involves incompliance with ATC procedures; for instance, failure to respond to an unanswered call, not responding to alarm, not identifying aircraft, failure to terminate radar services, not issuing approach clearance, not giving reasons for vectoring information, failure to deliver information to aircraft, etc.

- **Instruction Error**

This occurs while conducting control procedures and communications. Specifically, there are errors such as delivery of incorrect information, issuing descent instruction late, issuing flight phase change instruction late, direction instruction error and clearance instruction error. Table 1.1 describes Structure of

ATC human error elements, category of error, its explanation and operational definition.

CATEGORY	**EXPLANATION**	**OPERATIONAL DEFINITION**
Communication Error	Difficulties in communicative interaction or aeronautical operations	Incorrect Read back Not challenged
		Wrong call sign Used
		Non-standard Phraseology
		Missed call
		Callsign Omission/Truncation
		Clipped call
Procedure Error	Errors such as difficulties in following checklists	Failure to respond to unanswered call
		No/late response to alarm
		No level verification
		No Identification of aircraft
		Late/No Issuance of landing clearance

CATEGORY	**EXPLANATION**	**OPERATIONAL DEFINITION**
Instruction Error	Errors such as giving incorrect instructions	Incorrect information passed to aircraft
		Late descent
		Late change
		Altitude Instruction Error
		Heading Instruction Error
		Clearance Instruction Error

Table 1.1 Structure of ATC human error elements.

Courtesy: Air_traffic_control_human_errors.pdf

1.6 PROBLEM DEFINITION

Air traffic has increased dramatically in the past few years, mainly due to its comfortability and speed of travel, and this thereby created a revolution and rise in the airline industry and construction of new airports and runways. It has put additional pressure on air traffic control system that handles thousands of flights per day. To avoid delays and collisions, air traffic management has to work efficiently. The primary responsibility of an Air Traffic Controller is to instruct pilots in the air are given proper instructions and commands in controlled airspace to safely manoeuvre the aircraft from any dangerous situation and land the aircraft safely in an orderly fashion. Not only on the air but even on the ground it is the

Air Traffic Controller's responsibility to guide to the aircraft through the airport to the runway if it's a departing aircraft and to the parking bay if it has just arrived. The ground based controller must accomplish two main tasks. The first task is to ensure all aircrafts are safe. The second task is to provide information to pilots. Air Traffic Controllers, who maintain the flow of aircraft in and out of airports and in flight, are key to aviation safety. So this is well recognized as one of the most stressful jobs, requiring total concentration. Radar controllers, as opposed to tower controllers, also have to work in semi-darkness with an airplane full of passengers in their sight as a mere luminous blip on the screen. The 24/7 staffing of the Air Traffic system sometimes requires more than 40 hour days including nights and weekends. This creates physical as well as mental stress and results in human-errors. So Air Traffic Control ranks' 4^{th} in the all-time most stressful jobs in the world by Bureau of Labor Statistics.

The below table 1.2 shows the major airplane accidents due to air traffic control human factors. It also describes the location, information of the aircraft and the major cause for the air crash.

DATE	AIRCRAFT AND ACCIDENT OUTLINE	MAJOR CAUSE
1956/6	In the airspace over Grand Canyon, the United States, DC-7 aircraft of UAL and L-1049 aircraft of TWA (both flying under Instrumental Flight Rules (IFR)) had a mid-air collision at 20,000 feet, causing death of all 128 passengers.	Air traffic congestion Shortage of controlling facility Shortage of ATC manpower Insufficient delivery of Traffic information

DATE	AIRCRAFT AND ACCIDENT OUTLINE	MAJOR CAUSE
2002/7	While controlled by the ACC of Zurich, Switzerland, TU-154 aircraft of Russian Bashkirian Airlines and B757 cargo aircraft of the U.S. DHL were flying on a collision course at the same altitude (FL360). Both airplanes descended to avoid each other, then the Bashkirian aircraft collided at a right angle with the Boeing cargo aircraft at FL354, killing all 71 passengers.	ATC instruction error RADAR malfunction (Short Term Conflict Alert) Route congestion Shortage of ATC manpower

Table 1.2 Major airplane accidents related to ATC human factor.

Courtesy: Air_traffic_control_human_errors.pdf

1.7 OBJECTIVE

Since aviation is currently experiencing an enormous increase in aircraft flow and air traffic, it has put additional pressure on air traffic control system that handles thousands of flights per day. To avoid delays and collisions, air traffic management has to work efficiently and it's their responsibility to instruct pilots in controlled airspace to safely manoeuvre the aircraft from any dangerous situation and land the aircraft safely in an orderly fashion. Air Traffic Controllers, who maintain the flow of aircraft in and out of airports and in flight, are key to aviation safety. So this is well recognized as one of the most stressful jobs, requiring total concentration. Radar controllers, as opposed to tower controllers, also have to work in semi-darkness with an airplane full of passengers in their sight as a mere luminous blip on the screen. The continuous staffing of the Air

Traffic system sometimes requires more nights and weekends. This has created an additional responsibility mainly for the controllers and thus this results in physical as well as mental stress and might cause human-errors. So main objective of this project is to implement the concept of LSTM (Long Short Term Memory) in Air Traffic Services. Our goal is to automate a part of Air Traffic Services which is Approach and Clearance Control considering the normal or usual conditions alone.

1.8 KEYWORDS

Air Traffic Services play an important role in aviation. We all fly, but ATC's work, uses and importance are not known by many. In this new concept, the following are some keywords used.

- Aviation
- Air traffic Control
- Approach Control
- Clearance Control
- Voice recognition
- Call Sign
- Flight Plan

1.8.1 AVIATION

Aviation comes from the Latin word meaning "bird," an appropriate translation given that aviation deals with travel by air, specifically in a plane. Aviation refers to flying using an aircraft, like an airplane. It also includes the activities and industries related to flight, such as air traffic control. The biggest of the many uses of aviation are in air travel and military aircraft.

1.8.2 AIR TRAFFIC CONTROL

Air Traffic Control (ATC) is a service provided by ground-based Air Traffic Controllers who direct aircraft on the ground and through controlled airspace, and can provide advisory services to aircraft in non-controlled airspace. The primary purpose of ATC worldwide is to prevent collisions, organize and expedite the flow of Air Traffic, and provide information and other support for pilots. In some countries, ATC plays a security or defensive role, or is operated by the military.

1.8.3 APPROACH CONTROL

Aircraft control system needs to be incredibly managed and well-prepared to make the propellation of aircraft safe. Approach control is responsible for controlling all instrument flight operating within its area of responsibility. Approach control may serve one or more airfields, and control is exercised primarily by direct pilot and controller communications. It separates all aircraft, including large and small jet aircraft, according to the guidelines set out through the Terminal Radar Approach Control (TRACON) service.

1.8.3.1 Terminal Radar Approach Control (TRACON)

A TRACON is the name in the US for what is also known in other countries as the Terminal Control Center, the control in charge of operations close to one or more large airports (but not on the airports themselves). TRACON manage arrivals and departures, the related transitions to/from cruise, and also aircraft transiting in their area. The following are the services of TRACON:

- Safety alerts
- Traffic Services
- Limited radar vectoring (including assistance for VFR traffic) on a workload permitting basis
- Sequencing at locations where procedures have been established for this purpose and/or when covered in a Letter of Agreement (LoA)
- Will keep the pilot informed of the latest reported weather and actual field conditions such as current ceiling, runway visibility, surface winds, and runway conditions

1.8.4 CLEARANCE CONTROL

A clearance issued by ATC is predicated on known traffic and known physical airport conditions. An ATC clearance means an authorization by ATC, for the purpose of preventing collision between known aircraft, for an aircraft to proceed under specified conditions within controlled airspace i.e. Clearances are issued solely for expediting and separating air traffic and are based on known traffic conditions which affect safety in aircraft operation. The traffic conditions include:

- aircraft in the air;
- aircraft on the manoeuvring area;
- vehicles on the manoeuvring area;
- Obstructions not permanently installed on the manoeuvring area.

ATC clearances do not constitute authority to violate any applicable regulations for promoting the safety of flight operations or for any other purpose; neither do clearances relieve a pilot-in-command of any responsibility whatsoever in connection with a possible violation of applicable rules and regulations. If an air traffic control clearance is not considered suitable by the pilot-in-command of an aircraft, the flight crew may request and, if practicable, obtain an amended clearance.

1.8.5 VOICE RECOGNITION:

Voice recognition is alternatively referred to as speech recognition. Voice recognition is a computer software program or hardware device with the ability to decode the human voice. Voice recognition is commonly used to operate a device, perform commands, or write without having to use a keyboard, mouse, or press any buttons. Today, this is done on a computer with ASR (automatic speech recognition) software programs. In Air Traffic ensuring ATC systems, voice recognition turns speech to text and text to speech.

But introducing higher levels of automation in Air Traffic management (ATM) is the intensive use of voice radio communication to convey ATC instructions to pilots. Automatic speech recognition, which converts human speech into texts, can provide a solution to significantly reduce controllers' workloads and increase ATM efficiency. Automatic speech recognition, which converts human speech into texts, is currently captured through keyboard and mouse devices can provide a solution to significantly reduce Air Traffic Controllers' workloads and increase ATM efficiency. Fig 1.7 represents voice recognition.

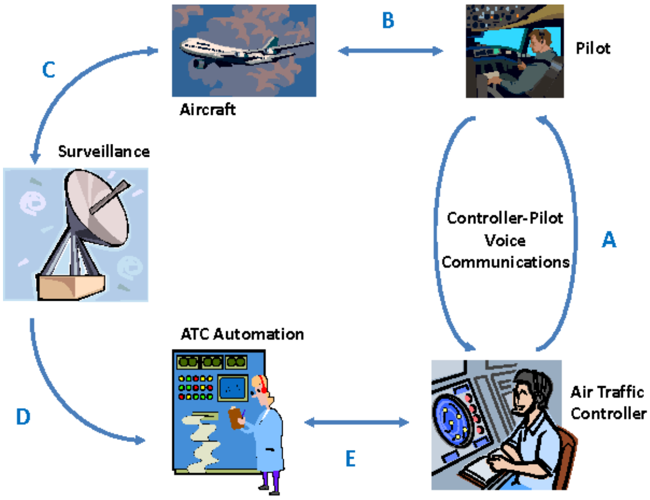

Fig 1.7 Voice recognition

Courtesy: Fsearchcustomerexperience.techtarget.com

1.8.6 CALL SIGNS:

Call signs in aviation are derived from several different policies, depending upon the type of flight operation and whether or not the caller is in an aircraft or at a ground facility. In most countries, unscheduled general aviation flights identify themselves using the call sign corresponding to the aircraft's registration number (also called *N-number* in the U.S., or *tail number*). In this case, the call sign is spoken using the International Civil Aviation Organization (ICAO) phonetic alphabet. Aircraft registration numbers internationally follow the pattern of a country prefix, followed by a unique identifier made up of letters and numbers. At times, general aviation pilots might omit additional preceding numbers and use only the last three numbers and letters.

1.8.7 FLIGHT PLAN:

An ATC flight plan is a document which provides specified information to Air Traffic service units relative to an intended flight or portion of a flight of an aircraft. (ICAO Annex 2: Rules of the Air) A navigation flight plan is a document prepared in accordance with the instructions of the operator contained in the Operations Manual and used in flight by the pilot to assist in navigation and safe operation of the aircraft. Detailed rules regarding submission, contents, completion, changes to, and closing of a flight plan are contained in ICAO Annex 2 (Rules of the Air) and in national flight information publications. A flight plan may be filed as a written document, an electronic document, or may be filed verbally. A flight plan contains such of the following information as is relevant to the flight:

- Aircraft identification
- Flight rules and type of flight
- Number and type(s) of aircraft and wake turbulence category
- Equipment
- Departure aerodrome
- Estimated off-block time
- Cruising speed
- Cruising level
- Route to be followed
- Destination aerodrome and total estimated elapsed time
- Alternate aerodrome
- Fuel endurance
- Total number of persons on board

- Emergency and survival equipment
- Other information.

All these essential information will be provided by the pilot, which is all about the plane that he is going to operate and submits this flight plan to the Chief controller. Fig 1.8 shows the real time flight plan of Sri Lankan Airlines.

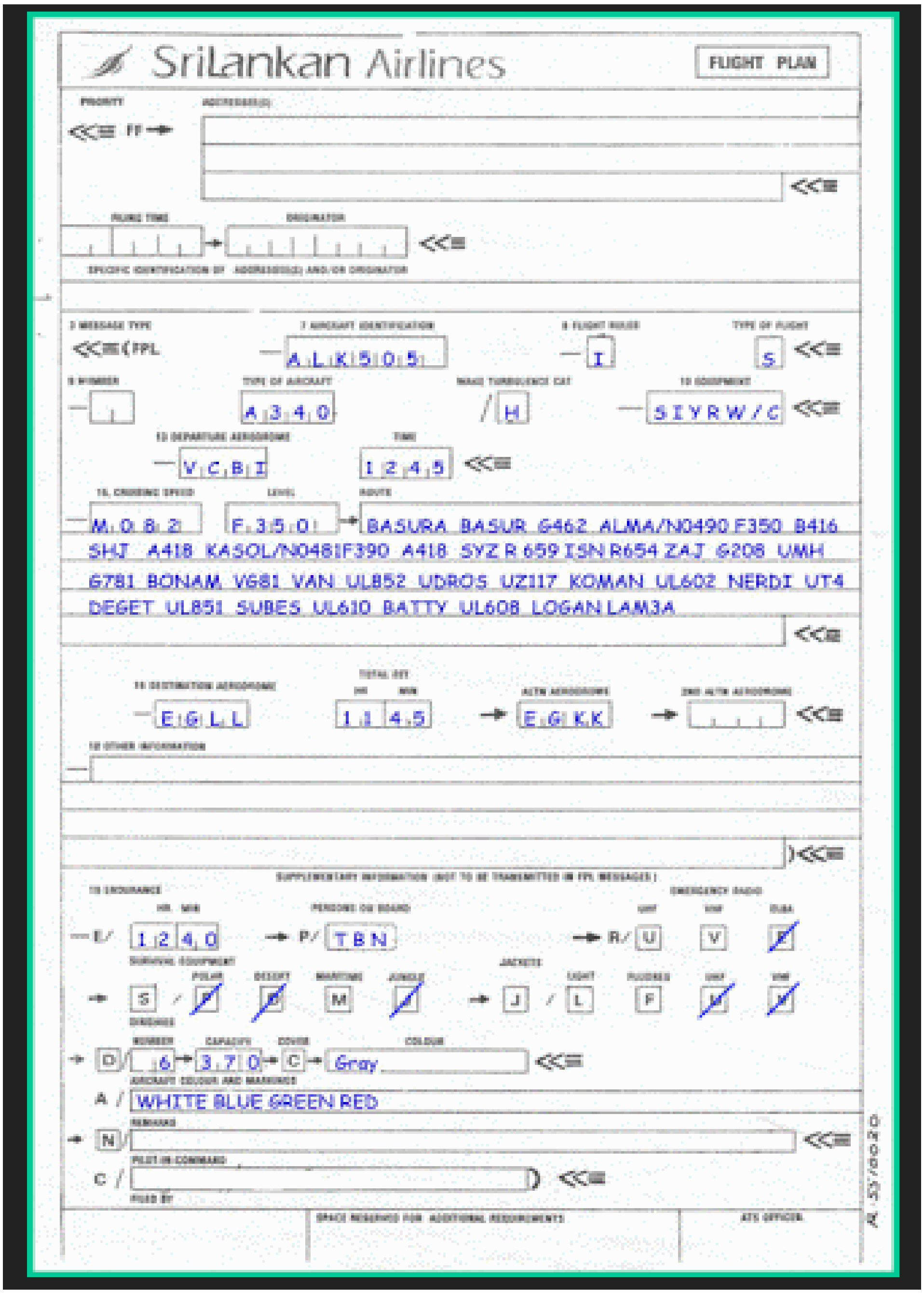

Fig 1.8 Flight Plan of Sri Lankan Airlines

Courtesy: atcsl.tripod.com

1.9 AN OUTLINE OF EXISTING SYSTEM

Air traffic control (ATC) is a service provided by ground-based air traffic controllers who direct aircraft on the ground and through controlled airspace, and can provide advisory services to aircraft in non-controlled airspace. Not only on the air but even on the ground it is the Air Traffic Controller's responsibility to guide to the aircraft through the airport to the runway if it's a departing aircraft and to the parking bay if it has just arrived. The ground based controller must accomplish two main tasks. The first task is to ensure all aircrafts are safe. The second task is to provide information to pilots. This information is related to the traffic and weather. Automatic Dependence Surveillance-Broadcast (ADS-B) radar technologies and given guidance and information that is requested or required by the pilot for the safe passage of flight through that region. To prevent collisions, ATC enforces traffic separation rules, which ensure each aircraft maintains a minimum amount of empty space around it at all times. In many countries, ATC provides services to all private, military, and commercial aircraft operating within its airspace. Depending on the type of flight and the class of airspace, ATC may issue instructions that pilots are required to obey, or advisories (known as flight information in some countries) that pilots may, at their discretion, disregard. The pilot in command is the final authority for the safe operation of the aircraft and may, in an emergency, deviate from ATC instructions to the extent required to maintain safe operation of their aircraft. Radar controllers, as opposed to tower controllers, also have to work in semi-darkness with an airplane full of passengers in their sight as a mere luminous blip on the screen. The 24/7 staffing of the Air Traffic system sometimes requires more than 40 hour days including nights and weekends. Moreover Air Traffic Control ranks' 4^{th} in the all-time most stressful jobs in the world by Bureau of Labor Statistics. So existing system has a high impact in creating stress and burden to the controllers.

1.9.1 DISADVANTAGES OF EXISTING SYSTEM

- Only Ideal Conditions were considered for evaluating and simulating the correctness of the systems, which are not applicable in real-time.
- High chances of incorrect read back, using wrong call-signs, using non-standard phraseology, and missing and clipping the call sign.
- Errors such as delivery of incorrect information, issuing descent instruction late, issuing flight phase change instruction late, direction instruction error and clearance instruction error might happen.
- No recovery in case of an internal system failure.
- Noisy channels can lead to misinformation.
- Human Stress is not focused which might lead to human error.

1.10 SUMMARY

Air Traffic Controllers, who maintain the flow of aircraft in and out of airports and in flight, are key to aviation safety. So this is well recognized as one of the most stressful jobs, requiring total concentration. The 24/7 staffing of the Air Traffic system sometimes requires more than 40 hour days including nights and weekends. This creates physical as well as mental stress and results in human-errors. So Air Traffic Control ranks' 4th in the all-time most stressful jobs in the world by Bureau of Labor Statistics. Air Traffic Control is a tedious task and automating such task is a challenging one just because it deals with crores of money and precious human lives. By implementing this work in real time, we cannot replace an Air Traffic Controller as a whole. Practically considering, this system will reduce human intervention up to some extent. Because of this, the stress faced by the controllers will be considerably reduced. We thereby incorporate a new concept called RNN-LSTM in a totally different domain, Air Traffic Control.

CHAPTER – 2

LITERATURE SURVEY

2.1 INTRODUCTION

With the rise in the airline industry and construction of new airports and runways, air traffic has increased dramatically in the past few years. It has put additional pressure on air traffic control system that handles thousands of flights per day. To avoid delays and collisions, air traffic management has to work efficiently. They face many problems like weather, communication, frequency congestion, work pressure, noise etc. They need to be aware that what is going on in their space as well as other sectors around them. If a problem arises, they need to act on it at the very moment. It puts a lot of pressure on air traffic controllers. A bad weather means a bad day for them. A controller needs to master the flow of communication on that frequency. Air traffic control is managing 50,000 flights daily, so they have to handle many flights at the same time. It means checking the altitude so that they don't collide against. Plus, multiple flights pass in the same route and during such situation if a flight face problem, they need to give special attention. For such reason several research papers that includes speech synthesis and speech recognition, language modelling, error categories and incorporation of data mining and neural networks in air traffic services, were referred and surveyed which were more relevant and much similar to our idea and the key points of those papers were noted for the implementation of our project.

2.2 RESEARCH PAPERS

Below are the research papers, which were surveyed for gaining information about existing research works which are related to our project. By surveying these below mentioned literature survey papers, it helps to build knowledge in our field of working, Data mining in Aviation. The abstracts of the literature survey papers includes speech synthesis and speech recognition, language modelling, error categories and incorporation of data mining and neural networks in air traffic services.

2.2.1 Using LSTM Encoder-Decoder Algorithm for Detecting Anomalous ADS-B Messages

ADS-B (Automatic Dependence Surveillance - Broadcast) plays a major role in the safe navigation of airplanes and air traffic control (ATC) management. But there is a lack of security mechanisms in this system and hence it is exposable to many attacks. Although many solutions were proposed, there is still a need of additional participating nodes (or sensors) which helps in verifying the location of the airplane by analyzing its physical signal. But most airplanes fly with ADS-B deployed in it so, applying those modifications is a bit complicated. [1]So an alternative security solution for detecting anomalous ADS-B messages is proposed which aims at the detection of spoofed or modified fake ADS- B messages sent by an attacker. The LSTM encoder-decoder algorithm is modelled here for safeguarding ADS-B messages from imposters. Using this model, aircraft can autonomously evaluate received ADS-B messages, thus helps to identify deviations from the legitimate flight path. The major drawback is, no recovery, in case of an internal system failure.

2.2.2 Emotional Statistical Parametric Speech Synthesis Using LSTM-RNNs:

This paper studies the methods for emotional statistical parametric speech synthesis (SPSS) using recurrent neural networks (RNN) with long short-term memory (LSTM) units. Two modeling approaches, i.e., emotion-dependent modeling and unified modeling with emotion codes, are implemented and compared by experiments. In the first approach, LSTM-RNN based acoustic models are built separately for each emotion type. A speaker-independent acoustic model estimated using the speech data from multi-speakers is adopted to initialize the emotion-dependent LSTM-RNNS. Inspired by the speaker code techniques developed for speech recognition and speech synthesis, the second approach builds a unified LSTM-RNN-based acoustic model using the training data of a variety of emotion types. In the unified LSTM-RNN model, an emotion code vector is input to all model layers to indicate the emotion characteristics of current utterance. Experimental results on an emotional speech synthesis database with four emotion types (neutral style, happiness, anger, and sadness) show that both approaches achieve significant better naturalness of synthetic speech than HMM-based emotion dependent modeling.[2] The emotion-dependent modeling approach outperforms the unified modeling approach and the HMM-based emotion-dependent modeling in terms of the subjective emotion classification rates for synthetic speech. Furthermore, the emotion codes used by the unified modeling approach are capable of controlling the emotion type and intensity of synthetic speech effectively by interpolating and extrapolating the codes in the training set. The LSTM encoder-decoder algorithm is modelled here for safeguarding ADS-B messages from imposters. Using this model, aircraft can autonomously evaluate received ADS-B messages, thus helps to identify deviations from the legitimate flight path.

2.2.3 Application of Data Mining in Air Traffic Forecasting

Many study centres has developed a model for the purpose of Air Traffic forecasting by using off-the-shelf data mining and machine learning techniques. Recent developments use data mining algorithms to predict the likelihood of previously un-connected airport-pairs being connected in the future, and the likelihood of connected airport-pairs becoming un-connected. [3]Despite the innovation of this research, it does not focus on improving the FAA's existing methodology for forecasting future Air Traffic levels on existing routes, which is based on relatively simple regression and growth models. So different approaches are investigated for improving and developing new features within the existing data mining applications in Air Traffic forecasting. As part of future work, machine learning techniques such as clustering and neural networks are getting applied to improve this model's performance.

2.2.4 Intelligent Air Traffic Control using Neural Networks

The air traffic control systems is again one of the most complex jobs thus has increased its complexity due to increase in aircrafts and airports. The air traffic controllers are responsible for taking complex decisions such as take-off, landing etc. The controllers depend on various parameters such as availability of runway, climate conditions, and other meteorological parameters and make the decisions which are much complicated and are highly prone to errors. Safety has to be considered when it comes to automation. This project deals with automation of existing air traffic control system using neural networks which comes under artificial intelligence. This has been found to be effective in many fields for making important and complex decisions. Back propagation network algorithm is used here for decision making. [4]The network is trained using some predetermined inputs and later the network will be capable of making decisions of its own with minimal or zero error. But Only Ideal Conditions were considered for evaluating and simulating the correctness of the systems, which are not applicable in real-time.

2.2.5 Using Recurrent Neural Networks for Slot Filling in Spoken Language Understanding

Semantic slot filling is one of the most challenging problems in spoken language understanding (SLU). In this paper, we propose to use recurrent neural networks (RNNs) for this task, and present several novel architectures designed to efficiently model past and future temporal dependencies. Specifically, we implemented and compared several important RNN architectures, including Elman, Jordan, and hybrid variants. [5]To facilitate reproducibility, we implemented these networks with the publicly available Theano neural network toolkit and completed experiments on the well-known airline travel information system (ATIS) benchmark. In addition, we compared the approaches on two custom SLU data sets from the entertainment and movies domains. Our results show that the RNN-based models outperform the conditional random field (CRF) baseline by 2% in absolute error reduction on the ATIS benchmark. We improve the state-of-the-art by 0.5% in the Entertainment domain.

2.2.6 Long Short-Term Memory Based Recurrent Neural Network Architectures for Large Vocabulary Speech Recognition

Long Short-Term Memory (LSTM) is a recurrent neural network (RNN) architecture that has been designed to address the vanishing and exploding gradient problems of conventional RNNs. Unlike feedforward neural networks, RNNs have cyclic connections making them powerful for modeling sequences. They have been successfully used for sequence labeling and sequence prediction tasks, such as handwriting recognition, language modeling, and phonetic labeling of acoustic frames. The second approach builds a unified LSTM-RNN-based acoustic model using the training data of a variety of emotion types. However, in contrast to the deep neural networks, the use of RNNs in speech recognition has been limited to phone recognition in small scale tasks. [6]In this paper, we present novel LSTM based RNN architectures which make more effective use of model parameters to train acoustic models for large vocabulary speech recognition. We train and compare LSTM, RNN and DNN models at various numbers of parameters and configurations. We show that LSTM models converge quickly and give state of the art speech recognition performance for relatively small sized models.

2.2.7 TTS Synthesis with Bidirectional LSTM based Recurrent Neural Networks

Deep neural networks (DNN)-based text-to speech (TTS) systems have been recently shown to outperform decision-tree clustered context-dependent Hidden Markov Models (HMM) TTS systems. In this paper, Recurrent Neural

Networks (RNNs) with Bidirectional Long Short Term Memory (BLSTM) cells are adopted to capture the correlation or co-occurrence information between any two instants in a speech utterance for parametric TTS synthesis. [7] Experimental results show that a hybrid system of DNN and BLSTM-RNN, i.e., lower hidden layers with a feed-forward structure which is cascaded with upper hidden layers with a bidirectional RNN structure of LSTM, can outperform either the conventional, decision tree-based HMM, or a DNN TTS system, both objectively and subjectively. The speech trajectory generated by the BLSTM-RNN TTS is fairly smooth and no dynamic constraints are needed.

2.2.8 Context Dependent Recurrent Neural Network Language Model:

Recurrent neural network language models (RNNLMs) have recently demonstrated state-of-the-art performance across a variety of tasks. In this paper, we improve their performance by providing a contextual real-valued input vector in association with each word. This vector is used to convey contextual information about the sentence being modeled. By performing Latent Dirichlet Allocation using a block of preceding text, we achieve a topic-conditioned RNNLM. [8]This approach has the key advantage of avoiding the data fragmentation associated with building multiple topic models on different data subsets. We report perplexity results on the Penn Treebank data, where we achieve a new state-of-the-art. We further apply the model to the Wall Street Journal speech recognition task, where we observe improvements in word-error-rate.

2.2.9 LSTM Neural Networks for Language Modelling

Neural networks have become increasingly popular for the task of language modeling. Whereas feed-forward networks only exploit a fixed context length to predict the next word of a sequence, conceptually, standard recurrent neural networks can take into account all of the predecessor words. On the other hand, it is well known that recurrent networks are difficult to train and therefore are unlikely to show the full potential of recurrent models. [9]These problems are addressed by the Long Short-Term Memory neural network architecture. In this work, we analyze this type of network on an English and a large French language modeling task. Experiments show improvements of about 8 % relative in perplexity over standard recurrent neural network LMs. In addition, we gain considerable improvements in WER on top of a state-of-the-art speech recognition system.

2.2.10 Air Traffic Volume and Air Traffic Control Human Errors

Abstract Navigable airspaces are becoming more crowded with increasing air traffic, and the number of accidents caused by human errors is increasing. Based on many interviews, study, research and surveys of ATC safety experts, the ATC errors are categorized into three major categories. They are communication error, procedure error, and instruction error. The main objective of this paper is to evaluate the relationship between air traffic volume and human error in air traffic control (ATC). First, the paper identifies categories and elements of ATC human error through a review of existing literature, and a study through interviews and surveys of ATC safety experts. [10]And then the paper presents the results of an experiment conducted on 52 air traffic controllers sampled from the Korean ATC organization to find out if there is any relationship between traffic volume and air traffic controller human errors. An analysis of the experiment clearly showed that several types of ATC human error are influenced by traffic volume. We hope that the paper will make its contribution to aviation safety by providing a realistic basis for securing proper manpower and facility in accordance with the level of air traffic volume.

2.2.11 Data mining for air traffic flow forecasting: a hybrid model of neural network and statistical analysis

The objective of this paper is to build a hybrid model of neural network and statistical analysis of air traffic flow. The air traffic flow prediction plays a key role in the airspace simulation model and air traffic flow management system. In China the air traffic information in each regional control center has not integrated together by now. The information only in a single regional control center cannot reach the requirement of the current method based on 4-dimensional trajectory prediction. The new method is needed to solve this problem. Large collection of radar data is stored. But there is no effort made to extract useful information from the database to help in the estimation. [11]Data mining is the process of extracting patterns as well as predicting previously unknown trends from large quantities of data. This paper employs neural networks combined with the statistical analysis of historical data to forecast the traffic flow. Two models with different types and input data are proposed. The accuracy of two models is tested and compared to each other using flow data at an arrival fix in Beijing control center. This has been found to be effective in many fields for making important and complex decisions. Back propagation network algorithm is used here for decision making. The result shows that these models are feasible for practical implementations. The suitable models for different prediction conditions are also suggested.

2.2.12 Speech recognition using Recurrent Neural Prediction Model

The neural prediction model (NPM) proposed by Iso and Watanabe is a successful example of a speech recognition neural network with a high recognition rate. This model uses multilayer perceptrons for pattern prediction (not for pattern recognition), and achieves a recognition rate as high as 99.8% for speaker-independent isolated words. [12]This paper proposes a recurrent neural prediction model (RNPM), and a recurrent network architecture for this model. The proposed model very significantly reduces the size of the network, with as high a recognition rate as the original model, and with a high efficiency of learning, for speaker-independent isolated words.

2.3 SUMMARY

Various dimensions and techniques of Air Traffic Control System were briefed in the survey paper. Above list of works were surveyed for several factors with respect to our proposed idea. The factors include processing and time efficiency along with the system processing. The efficiency of the model depends on how well it is used by the controllers and how far it will be useful for them to control the airflow on non-critical situations and ideal conditions. However, all these proposals have some disadvantages. No recovery in case of internal system failure. Noise is again a pretty concerning factor, which could leave to misinformation. The most common demerit in all these papers is, they don’t actually focus a bit much on the stress faced by the controllers, which could lead to human errors. So our model mainly focuses on this specific factor called “Human stress reduction” and automation is applied here to reduce their work pressure.

CHAPTER – 3

SYSTEM DESIGN

3.1 INTRODUCTION

Systems Design here is an important and powerful tool that helps us to overcome the complexity of existing systems i.e. in air traffic services and thus helps us to build a vision of our new work, where we are going to implement LSTM. Our system design describes the model that we are going to design, in a rich and diverse way. Every system emerges from the proper system design. Good plan leads to good design which in turn gives an efficient system. This proposed system includes a development phase to happen in a module by module manner. Software level development includes coding and integrating it as a single entity. For this development phase to become possible, the system design must be framed properly. In this chapter, system design is reflected with the illustration of various diagrams like system architecture, use case, activity, entity relationship and data flow diagrams.

3.2 SYSTEM ARCHITECTURE

Fig 3.1 represents the system architecture. The entities involved in this process are Pilot, Controller bot, Flight plan, Request/response DB and the process involved are Data Collection, Data Preprocessing, text processed audio based output. When the pilot contacts controller for approach/clearance, the actual working begins. Data collection is the first step in this process which is collected from flight plan given from the briefing room, where the actual procedure starts. More specifically the data includes Flight number, name, variant, from Airport, to airport, cruising speed and altitude, type, crew and passenger details and flight history. Then we analyze it according to the pilot needs and outer circumstances as the pilot approaches the system using voice commands. We generate appropriate text in order to generate response as audio to the pilot. Then LSTM is implemented and text processed audio based output is generated. Our project intends to develop an automated tool with help of Recurrent Neural networks, and data mining and Machine learning techniques and strategies are also used.

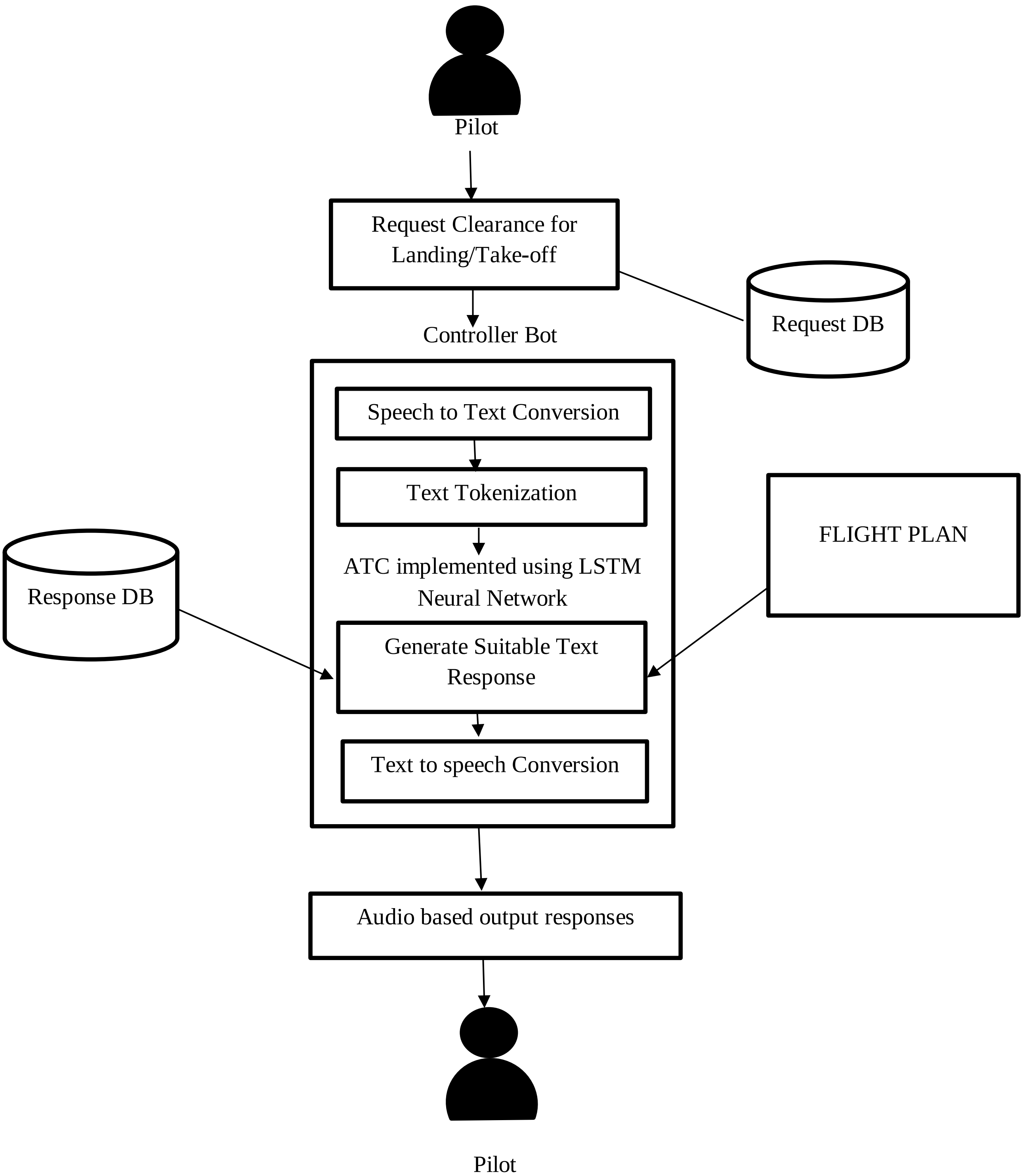

Fig 3.1 Proposed System Architecture

3.3 PROCESS FLOW

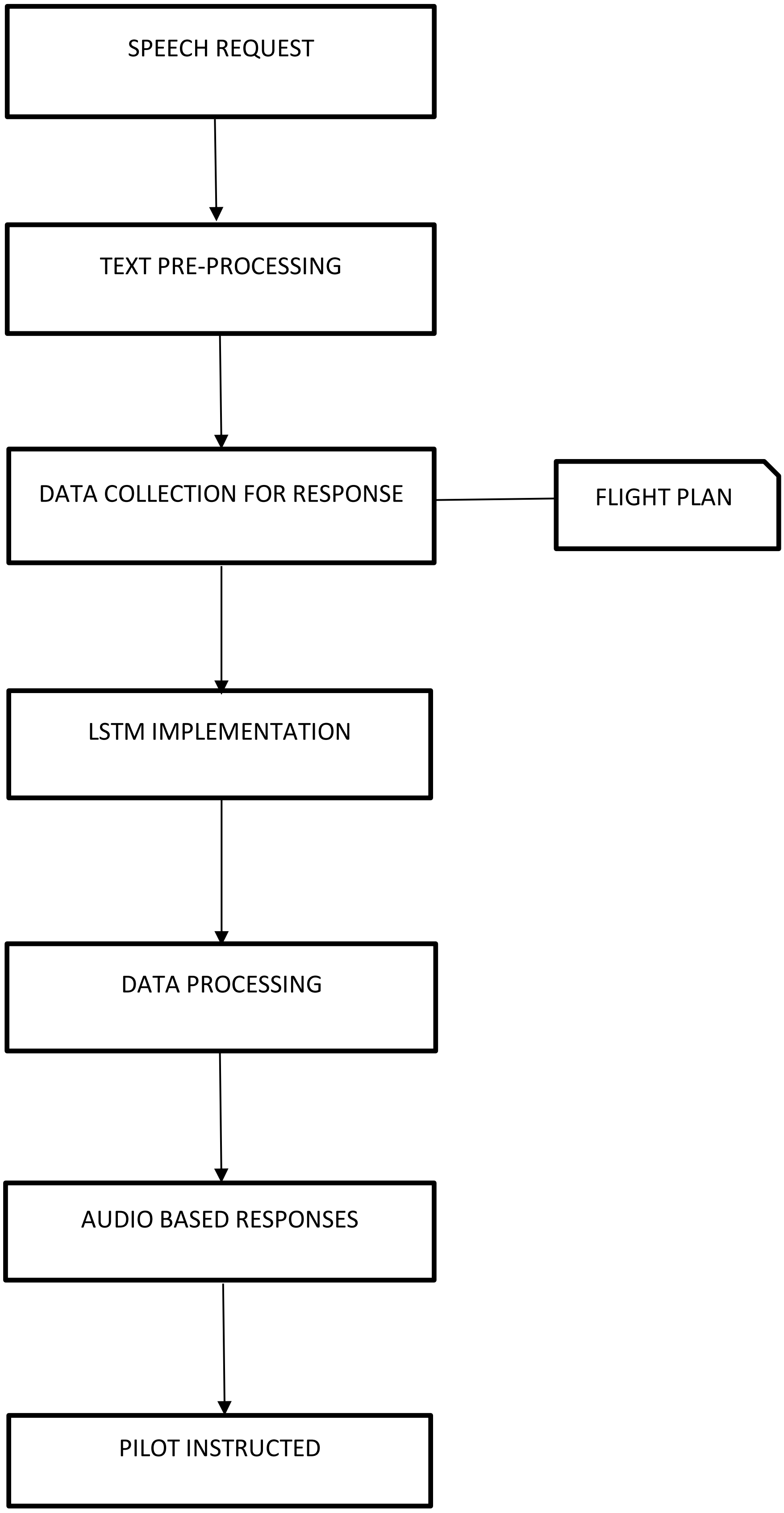

Fig 3.2 process flow

The process explains the systematic flow of predictive analytics process. The fig 3.2 represents the process flow of our project work. The entities involved in this process are Pilot, Controller bot, Flight plan, Request/response DB and the process involved are Data Collection, Data Preprocessing, text processed audio based output. It starts with Speech request from the pilot source. When the pilot contacts controller for approach/clearance, the actual working begins. The data collected is subjected to pre-processing where the data is made ready for analysis on various parameters. Data collection is the first step in this process which is collected from flight plan given from the briefing room, where the actual procedure starts. More specifically the data includes Flight number, name, variant, type, crew and passenger details and flight history. Then we analyze it according to the pilot needs and outer circumstances. Then LSTM is implemented and text processed audio based output is generated. Then data collection is performed from flight plan, which is again a source of response for pilots. Thus LSTM is implemented and data processing takes place. Then audio based output responses are generated as response to the pilot's request.

3.4 ENTITY RELATIONSHIP MODEL

Fig 3.3 represents the ER Diagram of Air Traffic Control System. The entities of Air Traffic Control System are Pilot, Air Traffic Control Tower/Room, briefing Room and aircraft that the pilot flies. The pilot controls an aircraft and consults ATC for approach/clearance. Thus the pilot and ATC possess "has" relationship. The ATC tower "has a" briefing room, where flight plan is obtained. Air traffic Control tower and Controller bot possess "has a" relationship. Each and every entity will have their attribute. Here, Pilot's attributes are Name, Age, and experience. Likewise, the attribute of ATC is ID. The attributes of Aircraft are Name and Registration No. Each and every entity of the system is linked to one another with different kinds of relationship which is one to one, one to many or many to many.

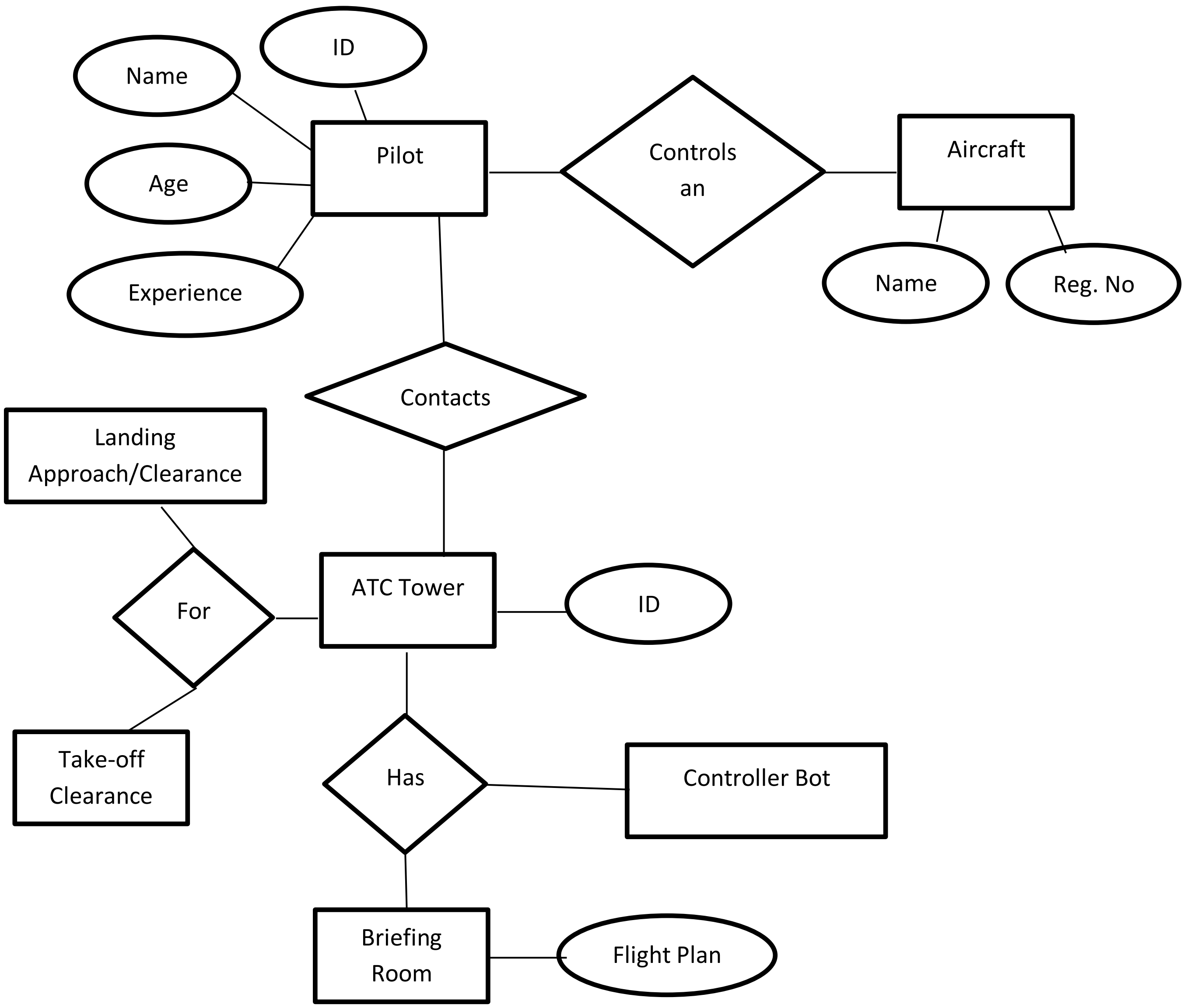

Fig 3.3 ER Diagram

3.5 DATA FLOW DIAGRAM

The Data Flow Diagram of Air Traffic Control System is represented below. The initial data is given as an audible form, which is converted to text in Speech-to-Text Process. The Converted text data is tokenized in the Text Tokenizer process. It then is processed using the data from the flight plans which is already restored with flight details such as name, variant, livery and other flight related and passenger related details, and the language dataset, to understand the intent of the command to produce a reply. The Process then creates a reply and it is converted into audible form and is sent to the pilot.

3.5.1 DFD Level 0

Fig 3.4 represents the data flow level 0. It is designed to be an at-a-glance view, because it explains the very basic flow of our system, that is easily understood by a wide audience, including stakeholders, business analysts, data analysts and developers. In the level 0 of data flow diagram explains the basic flow of the project. The input data contains the audio request and the final result is the audio response. The process between them involves speech/text processing.

Fig 3.4 DFD level 0

3.5.2 DFD Level 1

DFD Level 1 provides a more detailed breakout of pieces and explains more information of system flow than DFD level 0. In the below figure It highlights the main functions carried out by the system. Speech to text operation is performed over the speech request from the pilot and flight plan is involved here to provide flight data. Fig 3.5 shows DFD level 1.

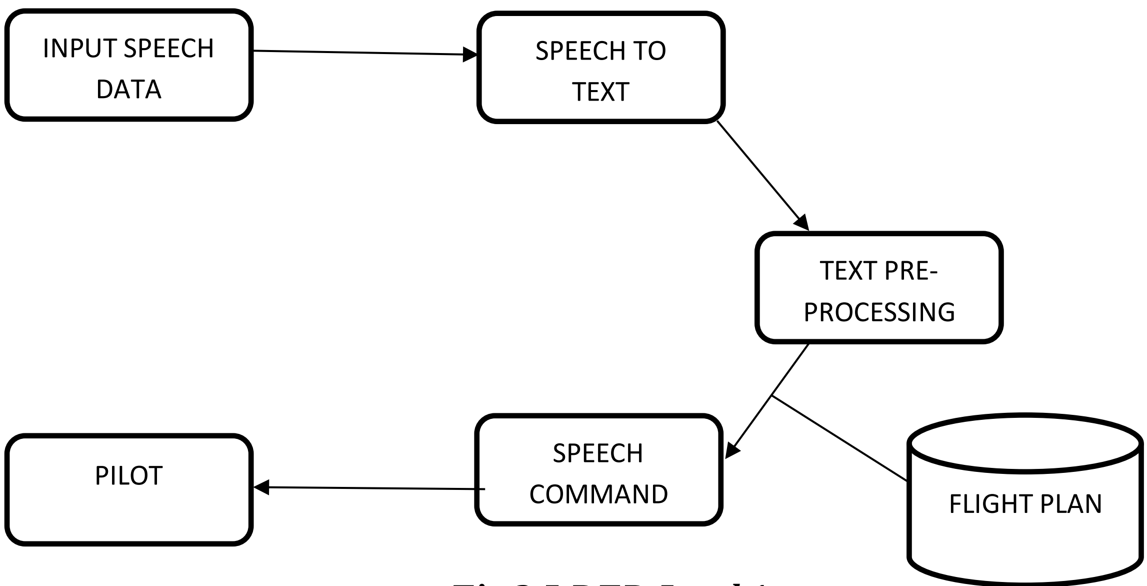

Fig 3.5 DFD Level 1

3.5.3 DFD Level 2

The DFD level 2 then goes one step deeper into parts of Level 1. Initially we process the pilot's request, as text. In Text tokenization process, the converted audio request from pilot that is converted into text is tokenized and stored. The unwanted and unnecessary stop words are removed from pilot's request. Now we create appropriate responses are initially generated as per the keywords that are stored. Then from the flight plan the flight data is fetched and combined with text data which comes as response to the pilot's request text, and combined as single statement with the help of LSTM called text pre-processing stage. Then the text is converted into audio output and supplied as response to the pilot's request. Fig 3.6 shows Level 2 DFD.

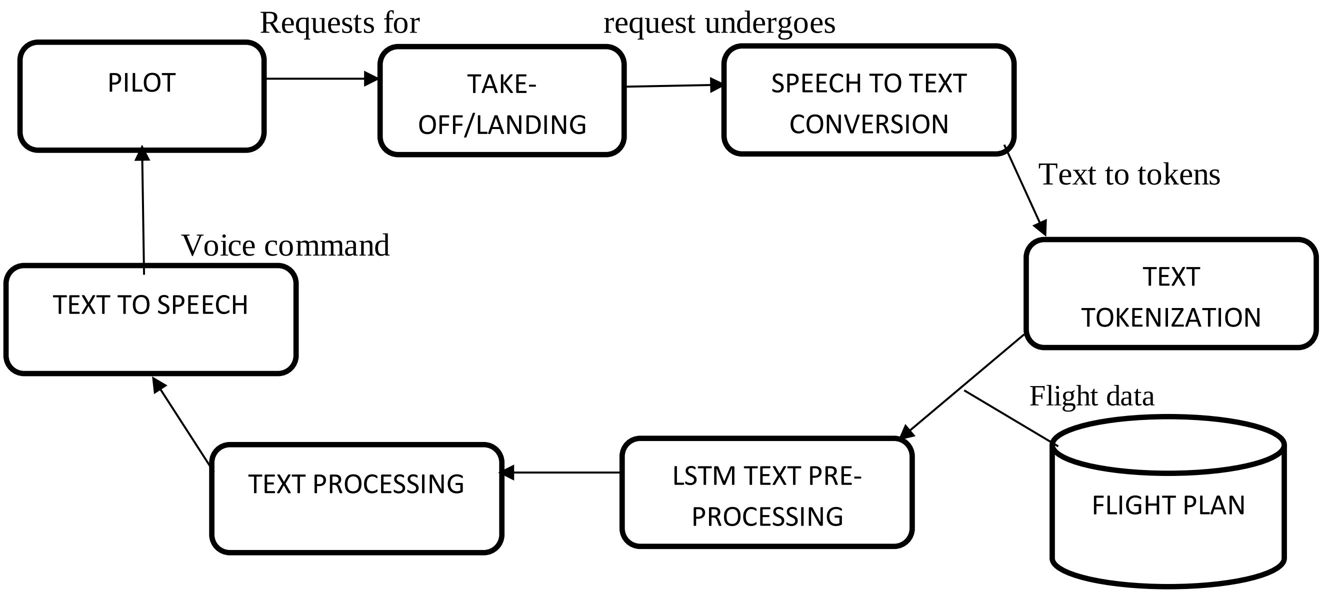

Fig 3.6 DFD Level 2

3.6 UML DIAGRAMS

The following UML diagrams are required for the project. They are

- Use Case Diagram
- Activity Diagram
- Class Diagram

3.6.1 USE CASE DIAGRAM

The Fig 3.7 represents the use case diagram of Air traffic control system. It contains actors (who perform the action) and the use cases (action or task). With the help of this diagram the user and the action performed by them is successfully identified.

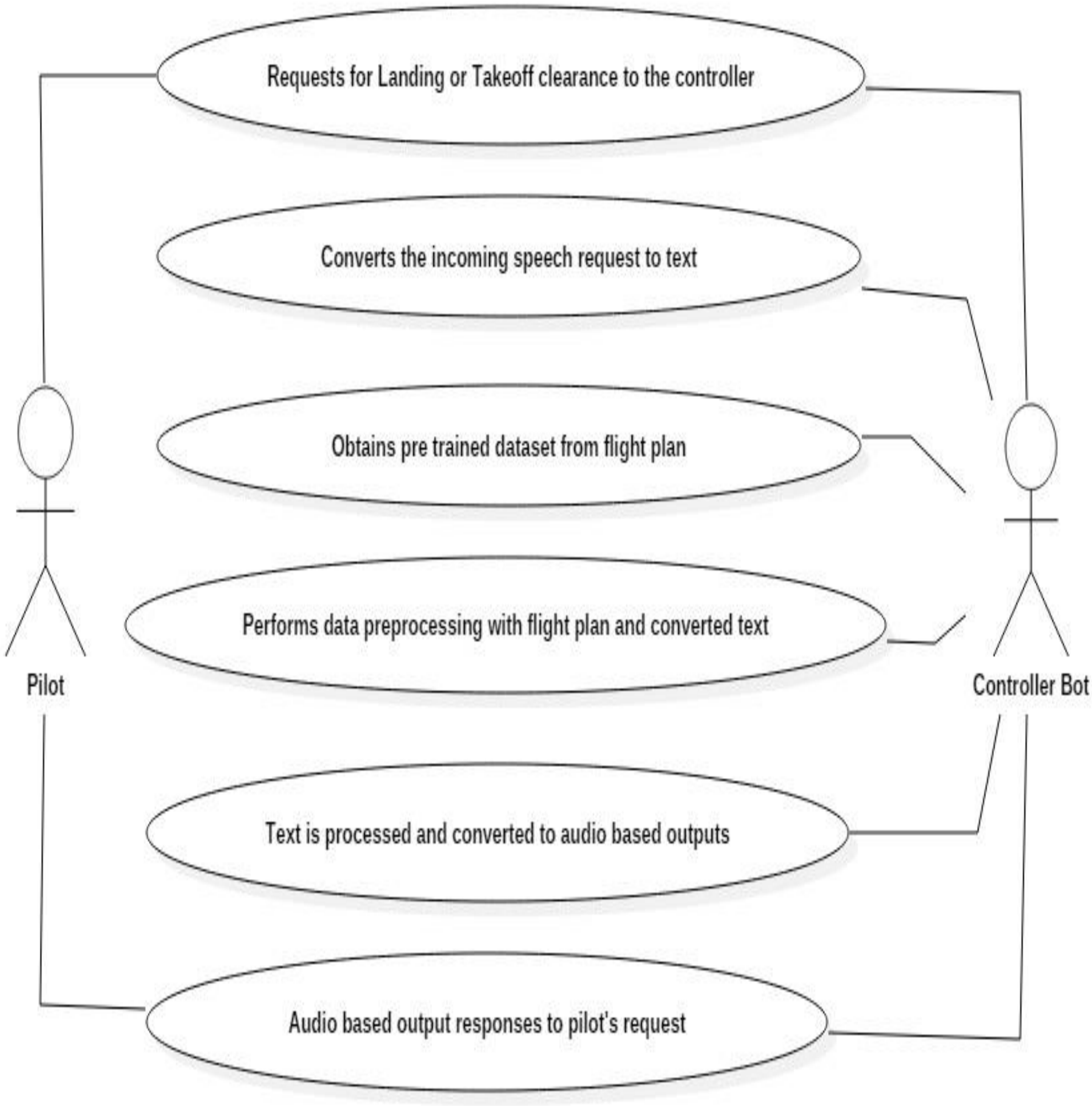

Fig 3.7 Use case Diagram

3.6.2 ACTIVITY DIAGRAM

Fig 3.8 here describes the activity diagram. Each activity has its own sub activities in the flow. Finally when the information is passed the activities comes to an end.

Here the diagram is classified in 4 vertical swim lanes, which are Pilot, AI (Chat bot), and Briefing Room, and Controller. The process flow starts with pilot's request for landing or take off. If normal conditions exist, then his response will be converted to text and text tokenization (data pre-processing) takes place. By doing this, the request will be classified and proper response is generated as text. This is converted to speech and is sent as a response to his/her request.

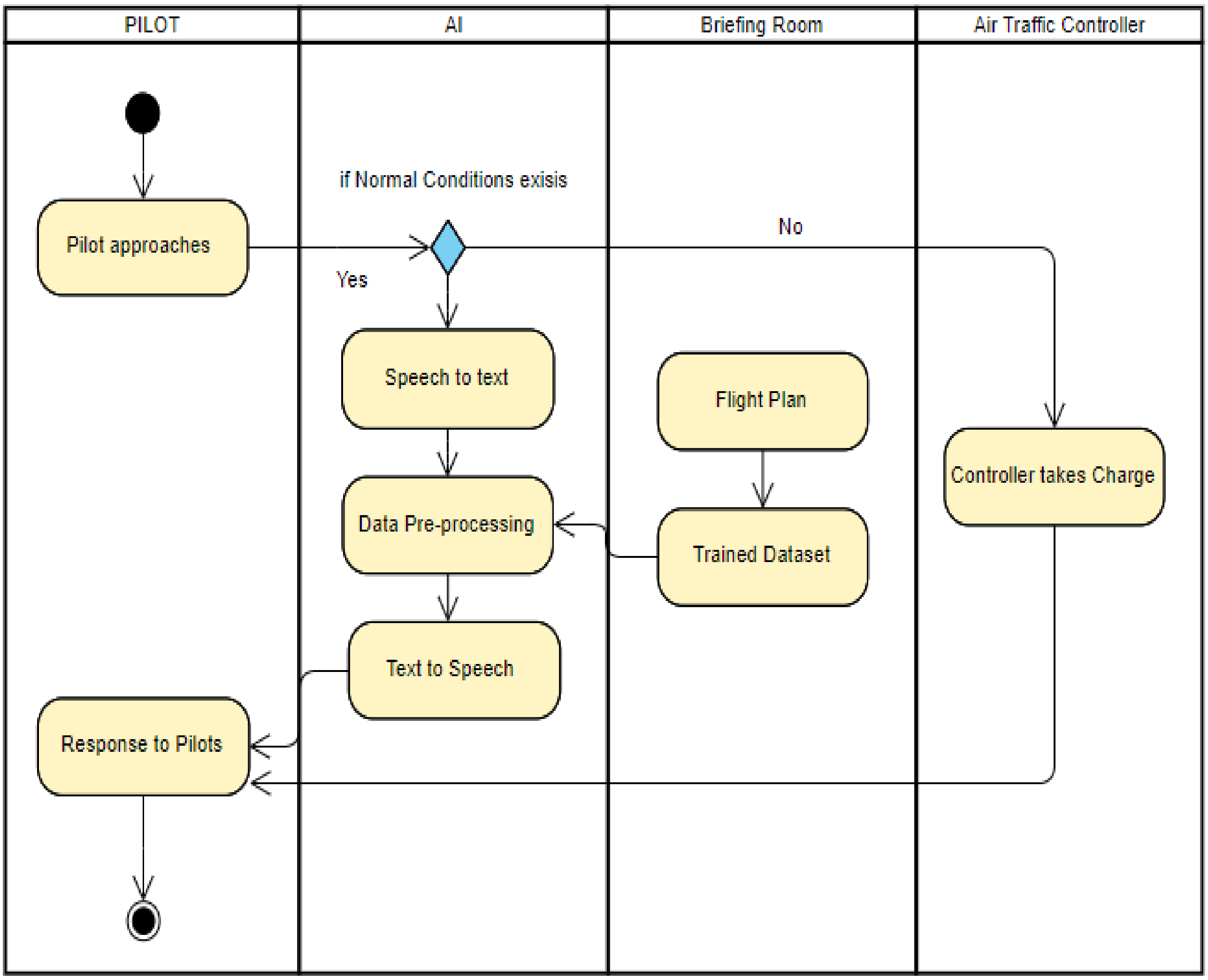

Fig 3.8 Activity Diagram

3.6.3 CLASS DIAGRAM

The classes involved in the class diagram of our system are Aircraft, Flight Plan, Pilot, Airport and Controller Bot. Most of the data is obtained from the flight plan class. The Pilot sends voice commands using the Landing_Request(). The Controller Class receives the command then using the data obtained from the flight plan class, it creates a response for the pilot. The Flight Plan Class has a one-to-one relationship with the Aircraft Class and Pilot Class. The Flight Plan Class has the PIC_ID and Aircraft_ID for accessing those two classes respectively.

Aircraft is a class and the attributes of the aircraft class are ID, name, Model, source, destination, speed and altitude and the operations performed by this class are take-off, En-route and landing. Airport is a class and the attributes are International Air Transport Association (IATA) id, International Civil Aviation Organization (ICAO) id, and airport name and airport location. Its operations include Arrival, departure and surface movement. Flight plan is another important class that holds Plan ID, aircraft ID and its name, model, Source and Destination ICAO, Estimated Time of arrival, estimated time of departure, Pilot in Command ID and Name, First Officer, passenger count and color of aircraft as attributes. Its operations are Input data and Retrieve data.

Pilot is a class and its attributes are Pilot ID, Pilot name, and his experience in hours of flight operation. His primary operations are aircraft control operations such as landing request, takeoff and runway request, and receive response. The next comes the controller Bot which has ID and command as the attributes and inspection and traffic monitoring, Receive request and send response as its operations. The aircraft has many to one relationship with airport. The pilot has one to one relationship with aircraft. The flight plan is associated with aircraft, airport, controller bot which has one to one, many to one, many to one, one to one relationships respectively. Fig 3.9 shows our system class diagram

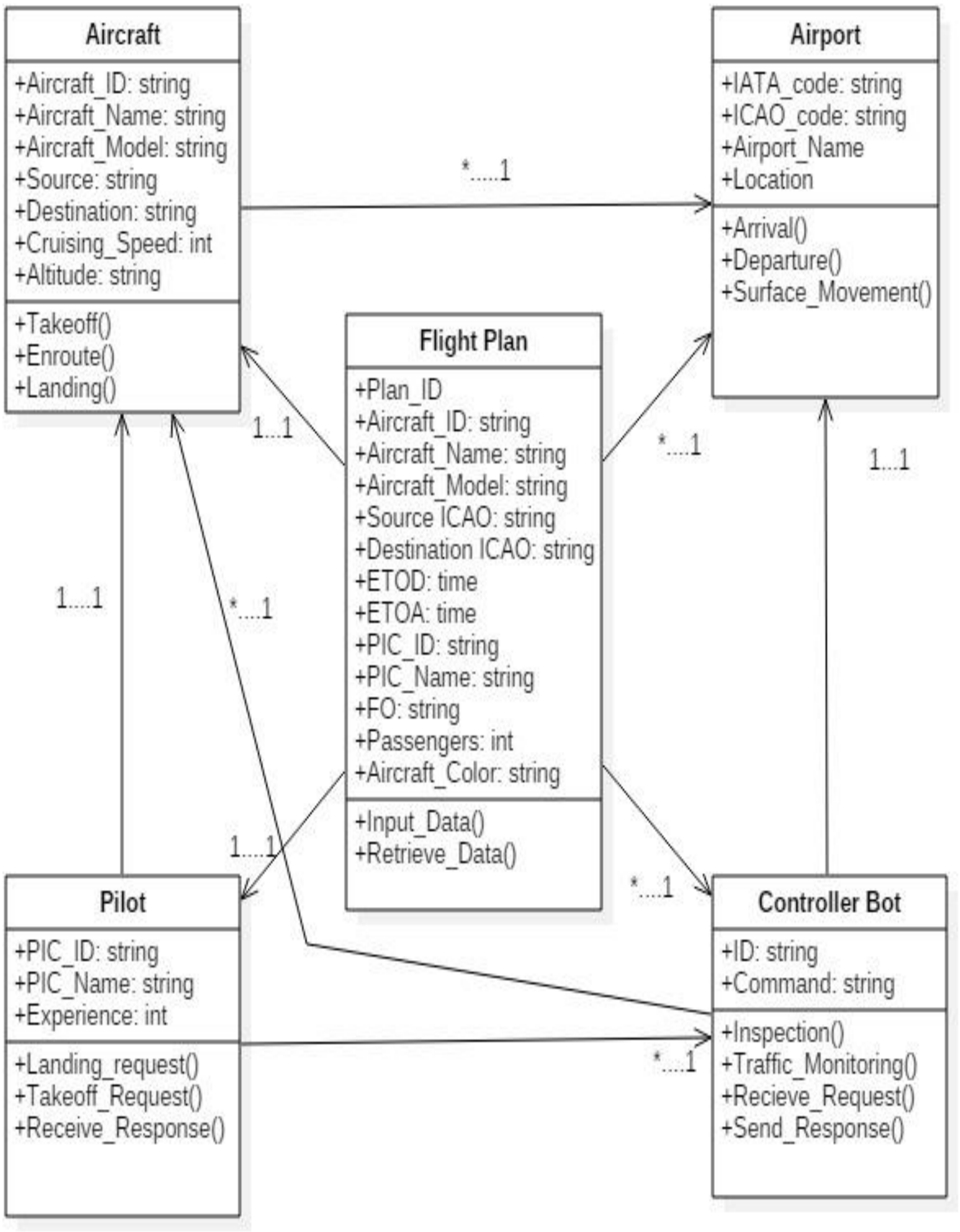

Fig 3.9 Class Diagram

3.7 SUMMARY

This chapter helps in making the system design efficient for the working of our system i.e. approach and clearance control which are the integral part of air traffic system and thus also helps in understanding and analyzing the nature of the system. Every UML diagrams owns its nature, usage, meaning and its role in the system. Also it briefs about the system in various perspectives like, as an actor's role, as sequence of activities, as the flow of data and their activities and the relationships between the entities, thus helps us to understand the basic architecture of the system. With this system design and the proposed system structure and the process flow, the diagrams explains us the data collection and segregation and the several stages of pre-processing, analysis, detection, prediction of our specialized air traffic system.

CHAPTER - 4

SYSTEM IMPLEMENTATION

4.1 INTRODUCTION

The disadvantages of the existing system in Air Traffic Services, had been discussed earlier. One disadvantage that we focus is “human stress”. In order to overcome this particular disadvantage, we are proposing a new solution to it in a creative way. The solution is framed in the domain of Data Mining and Machine Learning. 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 4 parts depending on its working. The factors considered for making these 4 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 4 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. In existing system he is responsible for safety maneuvering of aircraft. The standard method of communication between an air traffic controller and a pilot is voice radio, using either Very High Frequency (VHF) bands for line-of-sight communication or High Frequency (HF) bands for long-distance communication (such as that provided by Shanwick Oceanic Control). Fig 4.1 represents voice radio communication.

Fig 4.1 Voice radio Communication

Courtesy: Arabian Airspace

The busy controller in main control tower receives the request from the pilot and transfers the response. The main hardware components that we are going to use are shown in fig 4.2. A good performing Personal computer with internet connectivity and earphones for passing the input.

4.2 SYSTEM MODULES

The proposed system is segregated into 4 main modules, which are

- Speech request to text
- Text Summarization
- Response Generation
- Text response to Speech

All the above modules make up our system modules. These modules are individually made up for working. Each and every module possess an individuality in working and contributes equally for the overall working of our project. The required hardware components for our work is, a good featured personal computer and headphones/earphones for passing input and receiving output. The is all of a kind of Chat bot prototype as this is the initial stage of development in this highly esteemed field.

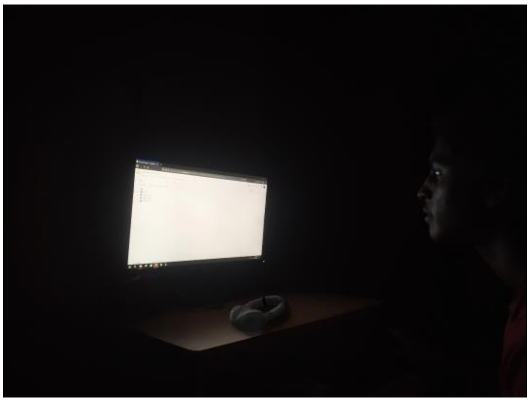

Fig 4.2 PC and earphones

Initially the audio (Speech request) has to be passed as input the system and the system responds after receiving the audio as shown in fig 4.3 and 4.4.

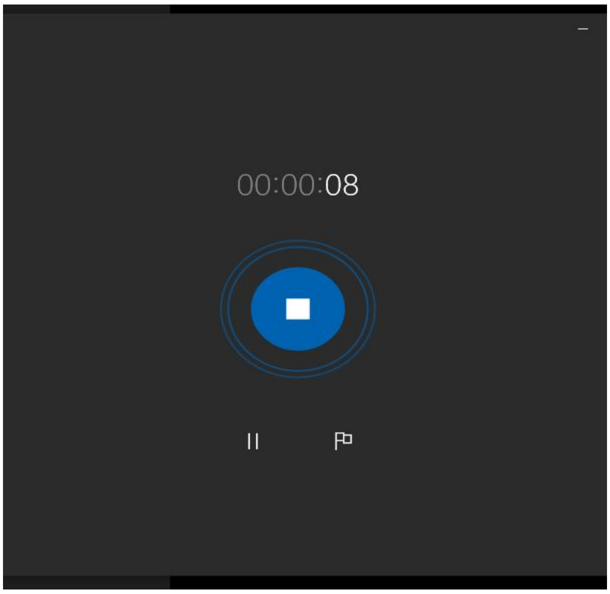

Fig 4.3 Audio input

```
r=sr.Recognizer()
harvard=sr.AudioFile(fn)
with harvard as source:
  audio = r.record(source)
if(audio):
  print("Audio Received Successfully")
else:
  print("Audio Error")
```

```
Audio Received Successfully
```

Fig 4.4 System Response after receiving audio

4.2.1 SPEECH REQUEST TO TEXT

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. Fig 4.5 and 4.6 illustrates speech to text process in our system. We initially pass an audio file as pilot's request in standard wav format to obtain text.

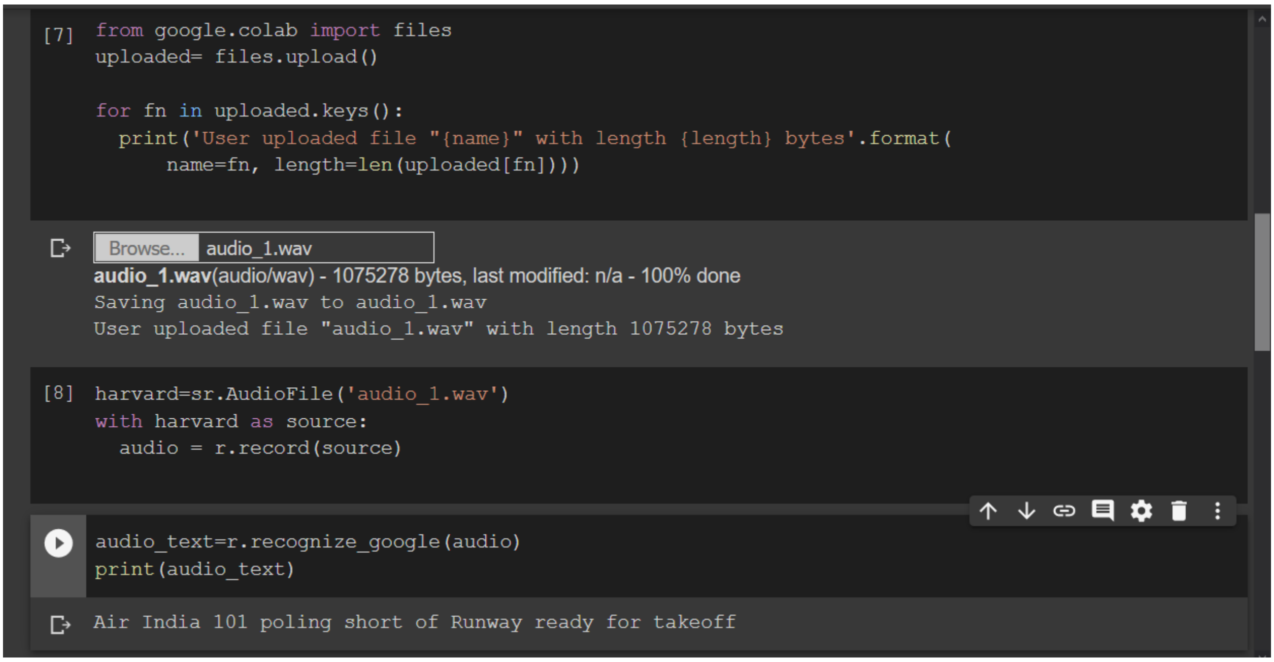

Fig 4.5 Audio converted to text

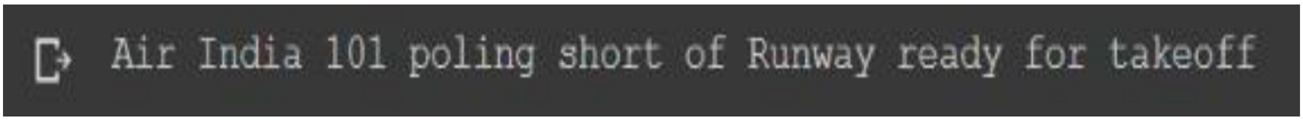

Fig 4.6 Converted text request.

4.2.2 TEXT SUMMARIZATION

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.

Fig 4.7 and 4.8 illustrates text Summarization process. In fig 4.5 we obtained text output from audio input. That output command text is fed as input to this text Summarization module. The natural language toolkit removes unwanted stop words, and obtains only the selective keywords, which is performed in fig 4.8

```
['Air', 'India', '101', 'poling', 'short', 'of', 'Runway', 'ready', 'for', 'takeoff']
['Air', 'India', '101', 'poling', 'short', 'Runway', 'ready', 'takeoff']
```

Fig 4.7 Tokenize text

```
[ ] import nltk
    nltk.download('stopwords')
    nltk.download('punkt')
    from nltk.corpus import stopwords
    from nltk.tokenize import word_tokenize
    stop_words = set(stopwords.words('english'))
    word_tokens = word_tokenize(audio_text)

    filtered_sentence = [w for w in word_tokens if not w in stop_words]

    filtered_sentence = []

    for w in word_tokens:
      if w not in stop_words:
        filtered_sentence.append(w)

    print(word_tokens)
    print(filtered_sentence)
```

```
[nltk_data] Downloading package stopwords to /root/nltk_data...
[nltk_data]   Package stopwords is already up-to-date!
[nltk_data] Downloading package punkt to /root/nltk_data...
[nltk_data]   Package punkt is already up-to-date!
['Air', 'India', '101', 'poling', 'short', 'of', 'Runway', 'ready', 'for', 'takeoff']
['Air', 'India', '101', 'poling', 'short', 'Runway', 'ready', 'takeoff']
```

Fig 4.8 Text Summarization

4.2.3 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.

Fig 4.9 shows response generation phase. We can clearly note that, the system has clearly responded to pilot’s request. 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.

```
import pandas
with open('response.csv', mode='r') as csv_file:
    csv_reader = csv.reader(csv_file,delimiter=',')
    request=[]
    response=[]
    actual_response=''
    i=0
    for row in csv_reader:
     request.append(str(row[0]))
     response.append(str(row[1]))
    for i in range(len(filtered_sentence)):
      for k in range(len(request)):
          if(filtered_sentence[i]==request[k]):
              actual_response=response[k]
  file = open("airlines.txt",'r')
  tmp=' '
  count=0
  while True:
  count+=1
  line=file.readline().replace('\n','.')
  tmp=line
  if (tmp in audio_text):
    found_flag=1
    print(actual_response+' '+tmp+'101')
Cleared for Takeoff  AirIndia 101
```

Fig 4.9 Response Generation

4.2.3.1 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.

4.2.4 TEXT TO PILOT RESPONSE

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 as shown in fig 4.10. The request-response conversation has to be quick and spontaneous.

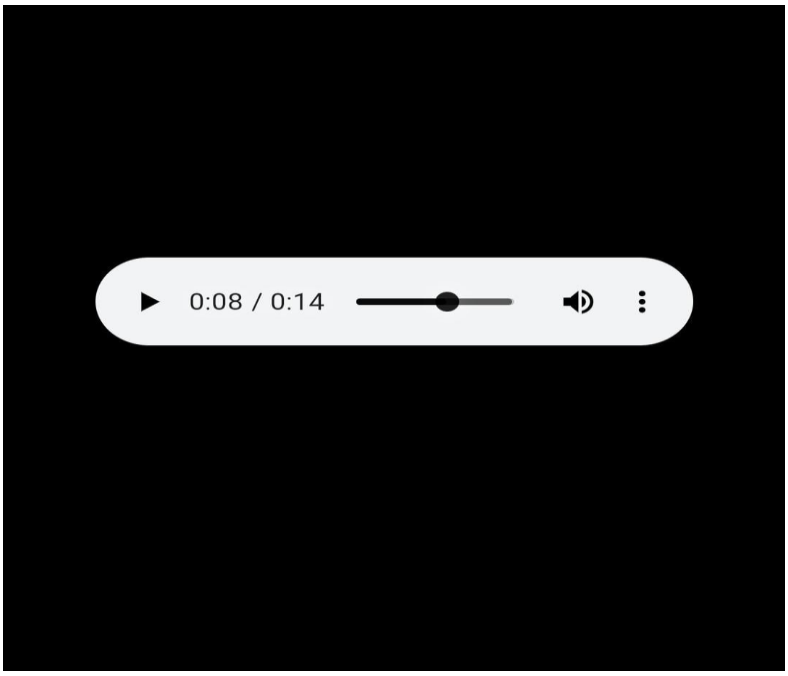

Fig 4.10 Audio response

4.3 SUMMARY

These are the 4 modules make up our automatic Controller Bot in Air Traffic Control System. It thereby helps the controller in maneuvering the aircraft safely under his/her surveillance and reduces their mental stress in a great manner. This automatic controller bot in Air Traffic Control System has to be spontaneous in action and also it will ensure that correct response is generated to pilots, as per their request. System is implemented as described in this chapter. And also the interconnection of the modules can be understood from this chapter. The working of each module is detailed along with its usage. The work of each module appears to be sequential. The minimum time for the entire process to complete after receiving request is expected to range from 30 seconds to 1 minute. This proves the spontaneity of the proposed controller bot.

CHAPTER - 5

TESTING

5.1 INTRODUCTION

In the previous chapter the implementation of the proposed system has been discussed. This chapter is about the difficulties we faced during implementation process and also in the functioning of the system. By performing testing on our proposed system, we identified the errors, unexpected outputs from the system, also the risks, its causes and effects. In our project we are performing the unit testing and regression testing. The proposed system contains 4 modules with various functionalities. They are Pilot request to text**,** Text summarization using LSTM**,** Response Generation, and text to audio response. Each and every module undergoes severe testing process. They work one after another, result of first module induces the module 2 i.e., sequential workflow can be observed in the proposed system. Controller bot assists controllers and ensures safety maneuvering of aircraft with certain conditions. If proposed workflow fails somewhere, the objective of our system is entirely lost. So testing every single module in our work is very essential and system failure will effect in paying many lives. Thus testing is done with various possible test cases to assess the system's efficiency and reliability. The modules of our system are tested by unit testing. During the testing phase, we faced lots of difficulties. To overcome this, we modified certain parts of implementation. Again we performed the testing process to ensure the proper and smooth functioning of the proposed system. By performing the testing process, the problems occur at user site can be reduced. Finally the regression testing is performed to ensure that the change made to the system does not affect the entire proposed system. The test cases that were considered give a brief idea on how the system behaves. If any deviation occurs in the normal behavior, it marks the inefficiency of the system. To the maximum extent, this testing will help us to avoid those inefficiency.

5.2 TEST CASES

The Table 5.1, 5.2 and 5.3 and 5.4 represents various test cases performed during the testing process. The tabular column contains test case Id (TC ID), scenario, secondary consideration, expected output, status and remarks. Scenario provides the information about the implementation process where testing is performed. Remarks provide a hint or comment about the scenario and also the alternatives that can be used. Secondary considerations include the parameter which also needs to be considered for the given test case. Status marks the success or the failure of the scenario.

5.2.1 MODULE 1 – PILOT REQUEST TO TEXT.

The Table 5.1 represents the test case scenarios for the Module-1. (Pilot request to text)

TC ID	SCENARIO	SECONDARY CONSIDERATIONS	EXPECTED OUTPUT	STATUS	REMARKS
TC01	Direct Audio Input	Device Microphones	Audio gets recorded and accepted.	Pass	The audio input of our system is directly passed through device microphones, without recording it as a separate audio file.

TC ID	SCENARIO	SECONDARY CONSIDERATIONS	EXPECTED OUTPUT	STATUS	REMARKS
TC02	Recorded Audio input file	The input audio must be in .wav format only.	Audio is accepted	Pass	In this case, the device microphone is not accessed. An audio file in specified format is passed as input into our system.
TC03	Input audio is converted to text	Verification of proper conversion	Audio is converted to text	Pass	The system performs speech to text conversion process. Moreover, it is verified that it converts the words to, appropriate text format properly.

TABLE 5.1 TEST CASES FOR MODULE 1

In this module, the pilot's request is converted to text. The audio request can be passed either directly by accessing the device earphones, else can be passed as a .wav recorded audio file. It is tested whether the system accepts the input in both the cases. Then the recorded/inserted audio request of the pilot must be converted to text format for further process. The testing is done here to check whether the system converts the audio file into text. Then the converted text has to be tested, whether it is converted into proper text or not. We initially faced some problems bringing the proper text out from the audio file. However, after certain modifications we rectified those issues and our test cases got passed. Finally our module 1, which is the conversion of pilot's request, is converted into text successfully without any flaws.

5.2.2 MODULE 2 – TEXT SUMMARIZATION USING LSTM

The Table 5.2 represents the test case scenarios for module-2. (Text Summarization using LSTM)

TC ID	SCENARIO	SECONDARY CONSIDERATIONS	EXPECTED OUTPUT	STATUS	REMARKS
TC04	Converted request text is passed for summarization	The input has to be in proper string format.	Accepted	Pass	The converted request text is accepted by the system after checking its format and passed for summarization process.

TC ID	SCENARIO	SECONDARY CONSIDERATIONS	EXPECTED OUTPUT	STATUS	REMARKS
TC05	Text summarization	The intent of the passed text is checked whether it is properly obtained through summarization.	Summarized text	Pass	The system will perform the checking process whether the text is passed in for summarization and checks whether the intent of our text is obtained and whether the input is converted to proper summarized form.

TABLE 5.2 TEST CASES FOR MODULE 2

The converted request text is accepted by the system after checking its format and passed for summarization process. The system will perform the checking process whether the text is passed in for summarization and checks whether the intent of our text is obtained and whether the input is converted to proper summarized form. Initially the proper summarized form with intent was not obtained. Then after several attempts, the summarized format is obtained with proper intent with accuracy.

5.2.3 MODULE 3 – RESPONSE GENERATION

The Table 5.3 represents the test case scenarios tested for module-3. (Response Generation from CSV).

TC ID	SCENARIO	SECONDARY CONSIDERATIONS	EXPECTED OUTPUT	STATUS	REMARKS
TC06	Summarized text is compared with CSV data.	Availability of data in CSV	Successful comparison	Pass	The summarized text is compared with the data in csv (flight plan). It is tested whether the comparison is correct or not.
TC07	Response Generation after comparison	Verification process	Relevant response for the pilot's request	Pass	After comparing the summarized text with CSV, it is tested whether the appropriate response for the pilot gets generated

TC ID	SCENARIO	SECONDARY CONSIDERATIONS	EXPECTED OUTPUT	STATUS	REMARKS
TC08	Incorrect summarization	No proper intent	No output response gets generated	Pass	Even though the text gets summarized but the expected summarized text is not obtained, it is tested that nothing gets generated from CSV.
TC09	Flight Detail Inclusion	Not Applicable	Flight details gets added to the response	Pass	After the response gets generated, it is tested whether the flight information is appending with the response.

TABLE 5.3 TEST CASES FOR MODULE 3

In this module, the summarized text is compared with the data in csv (flight plan). It is tested whether the comparison is correct or not the functionality of email notification is tested. After comparing the summarized text with CSV, it is tested whether the appropriate response for the pilot gets generated. Even though the text gets summarized but the expected summarized text is not obtained, it is tested that nothing gets generated from CSV. After the response gets generated, it is tested whether the flight information is appending with the response and found that the final response comes with flight detail included.

5.2.4 TEXT TO PILOT RESPONSE

The Table 5.4 represents the test case scenarios tested for module-4.

TC ID	SCENARIO	SECONDARY CONSIDERATIONS	EXPECTED OUTPUT	STATUS	REMARKS
TC10	Pilot Response	Does the response flow through a noise-less channel?	Pilot receives a flaw-less audio response for his request	Pass	After getting the final output as text response, it is converted to audio. Testing is applied here to check whether the pilot receives noise-less response or not.

TABLE 5.4 TEST CASES FOR MODULE 4

After getting the response from CSV, the information has to be appended with that response, which is the pre-final output. The pre-final output which the actual text response, is converted to audio. Then it is passed as response to pilot's request. The most critical thing is, the pilot has to receive response, without noise added with it. So testing is applied here to check whether the pilot receives noise-less response or not.

5.3 SUMMARY

The system is tested as single units with the help of unit testing which is just a specialized form of automated testing. The modules that were subjected to testing involve basic Speech to text process, Summarization and pre-processing, text to speech part. Each module is tested separately. In module 1, the pilot's request is converted to text. The audio request can be passed either directly by accessing the device earphones, else can be passed as a .wav recorded audio file. It is tested whether the system accepts the input in both the cases. Then the recorded/inserted audio request of the pilot must be converted to text format for further process. The testing is done here to check whether the system converts the audio file into text. Then the converted text has to be tested, whether it is converted into proper text or not. All the test cases in module-1 has passed, which is explained in table 5.1. In module-2 the converted request text is accepted by the system after checking its format and passed for summarization process. The system performed the checking process whether the text is passed in for summarization and checks whether the intent of our text is obtained and whether the input is converted to proper summarized form. All the test cases in module-2 has passed, which is explained in table 5.2. In module-3 the summarized text is compared with the data in csv (flight plan). It was tested whether the comparison is correct or not the functionality of email notification is tested. After comparing the summarized text with CSV, it was tested whether the appropriate response for the pilot gets generated. Even though the text gets summarized but the expected summarized text is not obtained, it is tested that nothing gets generated from CSV. After the response gets generated, it was tested whether the flight information is appending with the response and found that the final response comes with flight detail included. All the test cases in module-3 has passed, which is explained in table 5.3. In module-4 the response from CSV and the information has to be appended, which is the pre-final output. The pre-final output which the actual text response, is converted to audio. Then it is passed as response to pilot's request.

The most critical thing is, the pilot has to receive response, without noise added with it. So testing is applied here to check whether the pilot receives noise-less response or not. The test case in module-4 has passed, which is explained in table 5.4. The test cases that were considered also give a brief idea on how the system behaves.

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

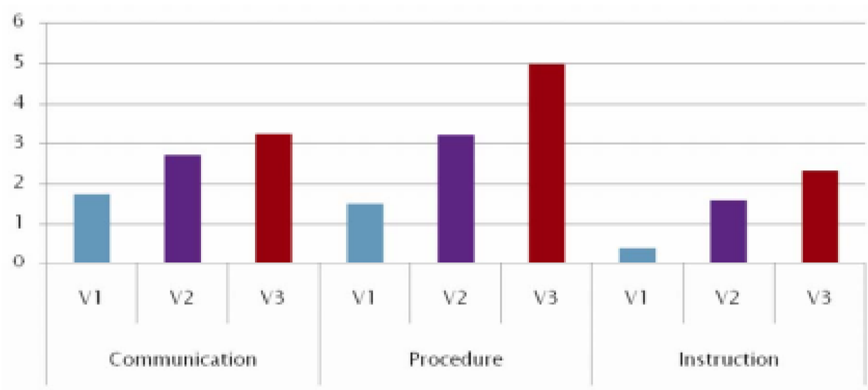

***Fig 6.2 error frequency by levels of air traffic volume*.**

Courtesy: Air traffic volume and human control errors.pdf

6.4ANALYSIS 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.

6.5 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.

6.5.1 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.

6.5.2 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.

6.5.3 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.

6.5.3.1 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.

6.5.4 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.

6.6 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.

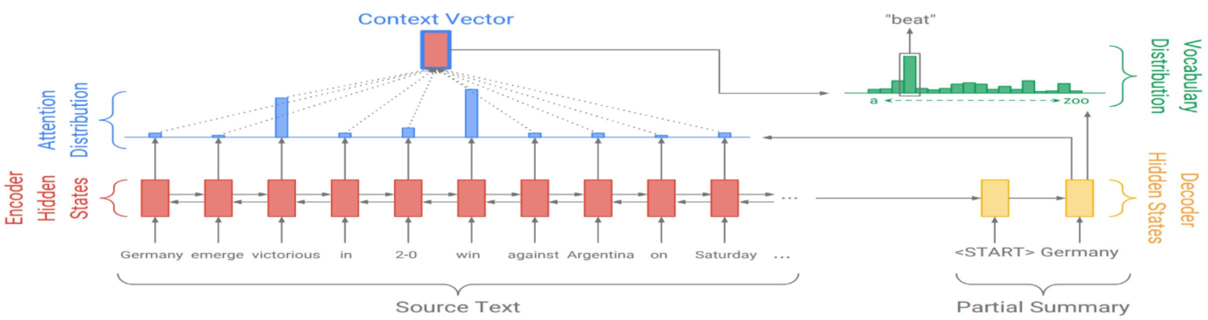

Fig 6.3 Text summarization using deep learning

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.

6.7 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.

CHAPTER - 7

FUTURE WORK

7.1 INTRODUCTION

Air Traffic Control is field of absolute dynamic decisions that include touch-and-go, go-around, emergency landing, and on-air fuel restoration (rare cases). So automating approach and clearance alone in normal conditions is a very little part. Because Air Traffic Services are not only meant for normal conditions. So planning to deploy dynamic decisions in our system has to be considered. Other environmental factors like traffic, weather has to be noted. In-order to achieve this, our system must be capable of decision making and has to possess that too. Our system works within the tower, for approach and clearance, replacing a regular controller. We had planned to enhance its features for s specific part called, “Departure Clearance”. After the boarding process takes place, the pilot runs a checklist before door-close. The pilot will be instructed to stay in gate, before pushback. Training our system for dynamic decision making is in our future plans.

7.2 FUTURE ENHANCEMENT

The two important stages that we are going to focus for future implementation are departure clearance and pushback clearance. The pilot initially asks for pushback clearance and then the flow goes on. Our plan is to bring automation here as a part of future work. We can develop a text interpreter. After asking for pushback clearance, the controller will say to clear the destination via some specific air space. Then pushback will be granted and pilot will be instructed to reach the runway, after the taxiing process. Then they have to switch over to tower again for clearing take-off, which is already automated as a part of our work. The total stages involved are stage-1 (departure clearance), stage-2 (pushback clearance), stage-3 (taxi clearance) and stage-4 (take-off clearance) which is already covered. Now automation is going to be applied from stage-1 to stage-3 as an entire process flow.

7.2.1 DEPARTURE CLEARANCE

The majority of commercial flights operate under Instrument Flight Rules (IFR). These flights are always given a clearance, usually before leaving the apron or gate where the airplane is parked. An ATC clearance allows an aircraft to proceed under specified traffic conditions within controlled airspace for the purpose of providing separation between known aircraft. A major contributor to runway incursions is lack of communication with ATC and not understanding the instructions that they give. The primary way the pilot and ATC communicate is by voice. The safety and efficiency of taxi operations at airports with operating control towers depend on this communication loop. ATC uses standard phraseology and require read-backs and other responses from the pilot in order to verify that clearances and instructions are understood. In order to complete the communication loop, the controllers must also clearly understand the pilot's read-back and other responses. Pilots can help enhance the controller's understanding by responding appropriately and using standard phraseology. Regulatory requirements, the AIM, approved flight training programs, and operational manuals provide information for pilots on standard ATC phraseology and communications requirements

Clearances are issued solely for expediting and separating air traffic and are based on known traffic conditions which affect safety in aircraft operation. The traffic conditions include:

- aircraft in the air;
- aircraft on the manoeuvring area;
- vehicles on the manoeuvring area;
- Obstructions not permanently installed on the manoeuvring area.

ATC clearances do not constitute authority to violate any applicable regulations for promoting the safety of flight operations or for any other purpose; neither do clearances relieve a pilot-in-command of any responsibility whatsoever in connection with a possible violation of applicable rules and regulations. If an air traffic control clearance is not considered suitable by the pilot-in-command of an aircraft, the flight crew may request and, if practicable, obtain an amended clearance. The clearance limit is described by specifying the name of the appropriate significant point, or aerodrome, or controlled airspace boundary. When prior coordination has been effected with units under whose control the aircraft will subsequently come, or if there is reasonable assurance that it can be effected a reasonable time prior to their assumption of control, the clearance limit shall be the destination aerodrome or, if not practicable, an appropriate intermediate point, and coordination shall be expedited so that a clearance to the destination aerodrome may be issued as soon as possible. Fig 7.1 describes pre-departure clearance.

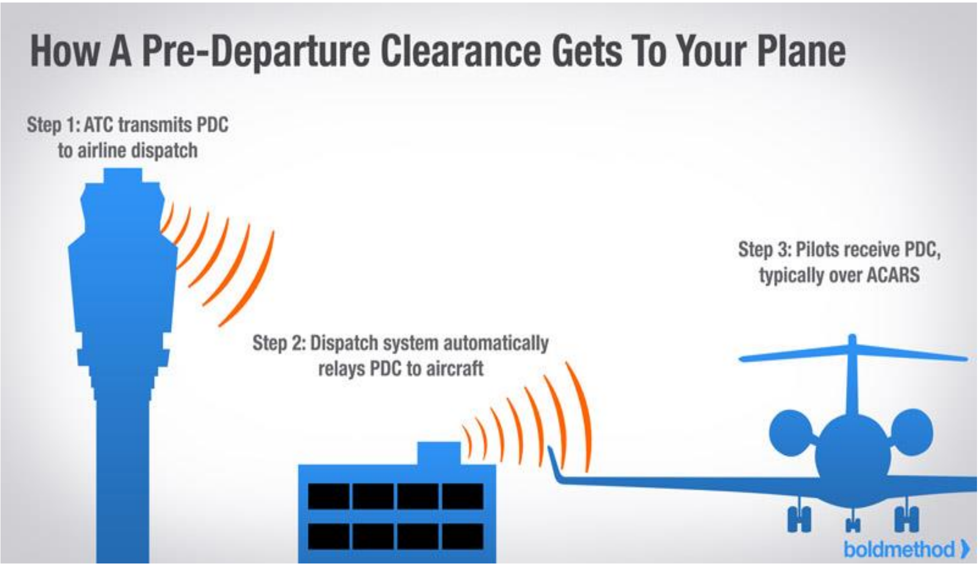

Fig 7.1 Pre-departure clearance

The route of flight is to be detailed in each clearance when deemed necessary. Subject to airspace constraints, ATC workload and traffic density, and provided coordination can be effected in a timely manner, an aircraft should whenever possible be offered the most direct routing. Instructions included in clearances relating to levels shall consist of:

- cruising level(s) or, for cruise climb, a range of levels, and, if necessary, the point to which the clearance is valid with regard to the level(s);
- levels at which specified significant points are to be crossed, when necessary;
- the place or time for starting climb or descent, when necessary;
- the rate of climb or descent, when necessary;
- Detailed instructions concerning departure or approach levels, when necessary.

Standard clearances for departing aircraft shall contain the following items:

1. aircraft identification;
2. clearance limit, normally destination aerodrome;
3. designator of the assigned SID, if applicable;
4. cleared level;
5. allocated SSR code;
6. Any other necessary instructions or information not contained in the SID description, e.g. instructions relating to change of frequency.

7.2.2 AUTOMATION IN DEPARTURE CLEARANCE

The Main tower controller will interact and involve in all the above mentioned stages. We have planned to incorporate automation of aircraft control from its engine start to engine stop. We have aimed to apply the same process of speech synthesis and text pre-processing in all the stages, as ATC is about decision making and proper communication. We are planning to set our system in the pilot-cockpit. The commands of the controller or the voice over commands will be obtained from the radio-telephony and undergoes text conversion process. Then the plan is to parse the text. Then the intent is obtained and displayed in cockpit dashboard, else it may also get printed. The main reason for doing this work is to provide a secondary safety purpose. We are not aiming to replace radio-communication, instead, it's just an additional confirmation and safety factor. This part is also in our future plan.

7.2.3 PUSHBACK

Pushback means the movement of an aircraft from a nose-in parking stand using the power of a specialized ground vehicle attached to or supporting the nose landing gear. It is commonly the second part of a 'Taxi In Push Out' (TIPO) procedure at airport terminal gates and will be necessary to depart from all except self manoeuvring parking stands unless the aircraft type is capable of power back and local procedures allow this. Occasionally, a pushback may need to be followed by an engines-running pull forward to a position where local procedures allow aircraft to move forward under their own power, but usually, ground vehicle disconnection will occur after the completion of a pushback. Once the aircraft commander (or other person in charge on the flight deck if the aircraft is not in service) has given their confirmation of 'brakes released' to the person in charge of the ground crew who are to carry out the pushback, the ground crew become temporarily responsible for the safe manoeuvring of the aircraft in accordance with either promulgated standard procedures or as specifically agreed beforehand.

Unless the manoeuvre is taking place outside the movement area controlled by ATC, an RTF clearance to carry it out will be required. Usually but not always, this will be obtained by the aircraft commander or other person in charge in the flight deck. The prescribed RTF phraseology for pushback is contained in ICAO PANS-ATM. Formerly, almost all aircraft types required that the ground locking pin be installed in the nose landing gear during any pushback; however, this is now no longer always the case. If a ground locking pin is installed for the pushback, it will need to be removed after the completion of the ground vehicle manoeuvre if the aircraft has been pushed back prior to intended flight. Both pushback methods are subject to the observance of any aircraft limits for maximum nose landing gear steering angle, but these are not usually especially restrictive.

The responsibilities of the ground crew team carrying out a pushback include ensuring that no part of the aircraft structure will impact any fixed object or other aircraft and may include giving clearance to start one or more engines just before, during or immediately after a pushback. The number of people assigned to a ground crew team for a pushback may vary according to aircraft size, but in most cases will be at least three. One will be driving the pushback vehicle, one will be walking in the vicinity of one of the aircraft wingtips and looking beyond the aircraft tail and one will be in charge of the manoeuvre and in communication with the person with aircraft responsibility in the flight deck. Communication between the ground crew supervisor is usually by means of a plug in to an aircraft ground intercom circuit; if so, this is facilitated by a ground crew microphone which acquires the voice of the user whilst excluding background noise, which if the aircraft engines are running can be considerable. If only two ground crew are used for pushback of a smaller aircraft then it is important that the procedure takes full account of the roles of each ground crewmember and that the person in charge of ground crew communications on the flight deck is aware of the number of ground crew being used and the physical location of the supervisor. Fig 7.2 shows pushback

Fig 7.2 Pushback

If it is considered that communication by hand signals rather than intercom is acceptable then it is essential that the applicable procedures are comprehensive and thoroughly understood by both parties and that they cover all possible abnormal and emergency circumstances. The case of engines-running pull forward as a supplementary action prior to ground vehicle disconnection after a pushback should be considered as part of the pushback procedure and trained accordingly since it bears little practical resemblance to the towing for longer distances of empty out-of-service with engines stopped. Engine Starts may be routinely accomplished immediately before or during pushback. Where they are carried out when the aircraft is moving, it is essential that the ground crew supervisor does not allow the checks and communication required in connection with engine starting to interfere with their primary responsibility to control the pushback and remain in full communication with those on the flight deck using the means available.

Many aircraft operators require that when push back is accomplished without headset communications, engine starts do not take place whilst the aircraft is being pushed, preferring instead to require that engine starting takes place before or after completion of the pushback. Observations of abnormal circumstances in connection with engine starts or any other matter affecting, or potentially affecting the safety of the aircraft during a pushback are of great importance to those on the flight deck but it is essential that any descriptions of external observations during engine starts are imparted accurately; this may sometimes be demanding using ground intercom but can be extremely difficult with only hand signals available.

7.2.3.1 THE KEY THREAT TO AIRCRAFT SAFETY

If damage is caused to the aircraft on pushback, or to another aircraft by the aircraft on pushback, this must be identified and technically assessed before that aircraft flies. Unfortunately, this is not always the case. It is important to recognize that when part of one aircraft impacts part of another aircraft, the degree of resultant damage may vary between negligible and major, even if the aircraft are identical. Ground Crews must be effectively briefed on this as well as other aspects of the operation. This is especially important when the ground crew are not employed directly by the aircraft operator or if they do not speak the same language fluently for operational communications.

7.2.3.2 ACCIDENTS AND INCIDENTS

The following events in the Skybrary database occurred during Pushback:

- A320, Bristol UK, 2019 (On 23 March 2019, the crew of a fully-loaded Airbus A320 about to depart Bristol detected an abnormal noise from the nose landing gear as a tow bar less tug was being attached. Inspection found that the aircraft nose gear had been impact-damaged rendering the aircraft no longer airworthy and the passengers were disembarked. The Investigation noted that tug driver training had been in progress and that the tug had not been correctly aligned with the nose wheels, possibly due to a momentary lapse in concentration causing the tug being aligned with the nose leg rather than the nose wheels.)
- A332, Karachi Pakistan, 2014 (On 4 October 2014, the fracture of a hydraulic hose during an A330-200 pushback at night at Karachi was followed by dense fumes in the form of hydraulic fluid mist filling the aircraft cabin and flight deck. After some delay, during which a delay in isolating the APU air bleed exacerbated the ingress of fumes, the aircraft was towed back onto stand and an emergency evacuation completed. During the return to stand, a PBE unit malfunctioned and caught fire when one of the cabin crew attempted to use it which prevented use of the exit adjacent to it for evacuation.)

- ATP, Jersey Channel Islands, 1998 (On 9 May 1998, a British Regional Airlines ATP was being pushed back for departure at Jersey in daylight whilst the engines were being started when an excessive engine power setting applied by the flight crew led to the failure of the tow bar connection and then to one of the aircraft's carbon fibre propellers striking the tug. A non-standard emergency evacuation followed. All aircraft occupants and ground crew were uninjured.)
- B738 / B738, Toronto Canada, 2018 (On 5 January 2018, an out of service Boeing 737-800 was pushed back at night into collision with an in-service Boeing 737-800 waiting on the taxiway for a marshaller to arrive and direct it onto the adjacent terminal gate. The first aircraft’s tail collided with the second aircraft’s right wing and a fire started. The evacuation of the second aircraft was delayed by non-availability of cabin emergency lighting. The Investigation attributed the collision to failure of the apron controller and pushback crew to follow documented procedures or take reasonable care to ensure that it was safe to begin the pushback.)
- B738, London Stansted UK, 2008 (On 13 November 2008, a Boeing 737-800 with an unserviceable APU was being operated by Ryanair on a passenger flight at night was in collision with a tug after a cross-bleed engine start procedure was initiated prior to the completion of a complex aircraft pushback in rain. As the power was increased on the No 1 engine in preparation for the No 2 engine start, the resulting increase in thrust was greater than the counter-force provided by the tug and the aircraft started to move forwards. The tow bar attachment failed and subsequently the aircraft’s No 1 engine impacted the side of the tug, prior to the aircraft brakes being applied.)
- B738, Singapore, 2015 (On 6 December 2015, a Boeing 737-800 was being maneuvered by tug from its departure gate at Singapore to the position where it was permitted to commence taxiing under its own power when the

tug lost control of the aircraft, the tow bar broke and the two collided. The Investigation attributed the collision to the way the tug was used and concluded that the thrust during and following engine start was not a contributory factor. Some inconsistency was found between procedures for push back of loaded in-service aircraft promulgated by the airline, its ground handling contractor and the airport operator.)

- B742, Stockholm Arlanda Sweden, 2007 (On 25 June 2007, a Boeing 747-200F being operated by Cathay Pacific on a scheduled cargo flight from Stockholm to Dubai had completed push back for departure in normal daylight visibility and the parking brakes had been set. The tow vehicle crew had disconnected the tow bar but before they and their vehicle had cleared the vicinity of the aircraft, it began to taxi and collided with the vehicle. The flight crew were unaware of this and continued taxiing for about 150 meters until the flight engineer noticed that the indications from one if the engines were abnormal and the aircraft was taxied back to the gate. The tow vehicle crew and the dispatcher had been able to run clear and were not injured physically injured although all three were identified as suffering minor injury (shock). The aircraft was "substantially damaged" and the tow vehicle was "damaged".)
- B752 / CRJ7, San Francisco CA USA, 2008 (On 13 January 2008, a Boeing 757-200 and a Bombardier CL-600 received pushback clearance from two adjacent terminal gates within 41 seconds. The ground controller believed there was room for both aircraft to pushback. During the procedure both aircraft were damaged as their tails collided. The pushback procedure of the Boeing was performed without wing-walkers or tail-walkers.)
- B763 / A320, Delhi India, 2017 (On 8 August 2017, a Boeing 767-300 departing Delhi was pushed back into a stationary and out of service Airbus A320 on the adjacent gate rendering both aircraft unfit for flight. The Investigation found that the A320 had been instructed to park on a stand that

was supposed to be blocked, a procedural requirement if the adjacent stand is to be used by a wide body aircraft and although this error had been detected by the stand allocation system, the alert was not noticed, in part due to inappropriate configuration. It was also found that the pushback was commenced without wing walkers.)

- B772 / A321, London Heathrow UK, 2007 (On 27 July 2007, a British Airways Boeing 777-200ER collided, during pushback, with a stationary Airbus A321-200. The A321 was awaiting activation of the electronic Stand Entry Guidance (SEG) and expecting entry to its designated gate.)
- B789 / A388, Singapore, 2017 (On 30 March 2017, a Boeing 787 taxiing for departure at night at Singapore was involved in a minor collision with a stationary Airbus A380 which had just been pushed back from its gate and was also due to depart. The Investigation found that the conflict occurred because of poor GND controlling by a supervised trainee and had occurred because the 787 crew had exercised insufficient prudence when faced with a potential conflict with the A380.

Safety Recommendations made were predominantly related to ATC procedures where it was considered that there was room for improvement in risk management.)

7.2.4 AUTOMATION IN PROVIDING ATIS DATA

As mentioned earlier Air Traffic Control is field of absolute dynamic decisions. We have planned to provide dynamic decisions and make the system trained for it. Mostly dynamic changes occurs in weather conditions, wind speed, wind direction and even clouds will be taken into consideration. Based on these factors, the runway for landing/take-off is set. Our Chennai Airport (MAA/VOMM) has 2 main runways, 07/25 (North East – South West Orientation) which lengths about 3.6 kilometers. The secondary runway 12/30 is rarely used. Runway usage alters based on ATIS data. To brief on ATIS in fig

7.3, it stands for Automatic terminal information service, which is a continuous broadcast of recorded aeronautical information in busier terminal areas.

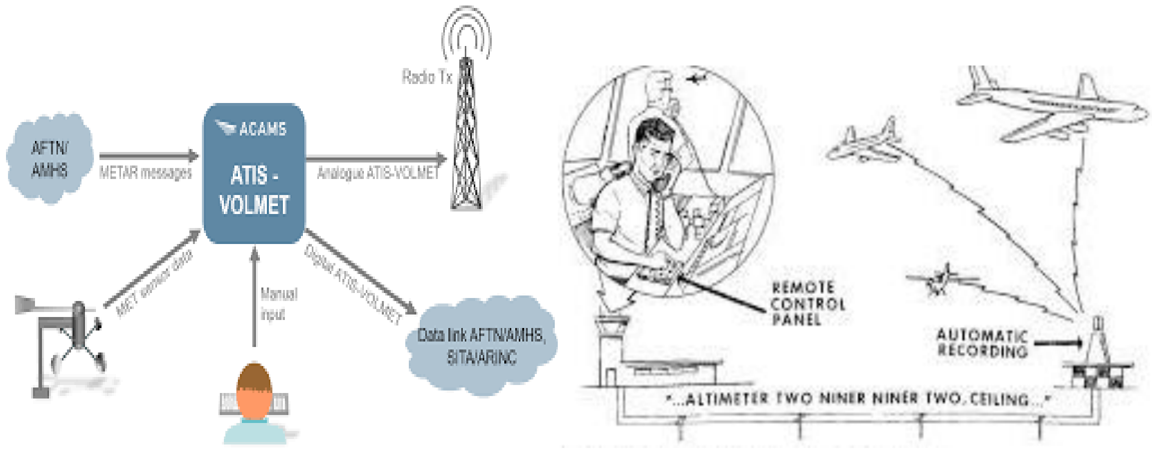

Fig 7.3 working of ATIS

Through ATIS we may able to broadcast essential information, like current weather information, active runways, available approaches, and any other information required by the pilots, such as important NOTAMs (NOtice To AirMen) . Pilots usually listen to an available ATIS broadcast before contacting the local control unit, which reduces the controllers' workload and relieves frequency congestion. By automating ATIS instructions for updating weather information, we can update visibility, present weather; cloud below 1500 meter or below the highest minimum sector altitude, cumulonimbus; if the sky is obscured, vertical visibility when available; air temperature; dew point temperature, altimeter setting(s); and any available information on significant meteorological phenomena in the approach and climb-out areas including wind shear, and information on recent weather of operational significance can be updated automatically.

7.3 SUMMARY

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.

By implementing this work in real time, we cannot replace an Air Traffic Controller as a whole. Practically considering, this system will reduce human intervention up to some extent. Because of this, the stress faced by the controllers will be considerably reduced. Our project intends to create an automated CHATBOT that process, analyses the output according to the input from the pilots. Thus this system will be great boon for controllers. If our future plans get executed, then it will create an impactful trend or even a benchmark in aviation sector.

APPENDIX A

SAMPLE SCREEN SHOTS

To start with, fig A1.1 represents animated representation of an Air Traffic Controller. In existing system he is responsible for safety maneuvering of aircraft.

Fig A1.1 Air Traffic Controller

Courtesy: VectorStock

The standard method of communication between an air traffic controller and a pilot is voice radio, using either Very High Frequency (VHF) bands for line-of-sight communication or High Frequency (HF) bands for long-distance communication (such as that provided by Shanwick Oceanic Control). Fig A1.2 represents voice radio communication.

Fig A1.2 Voice radio Communication

Courtesy: Arabian Airspace

The busy controller in main control tower receives the request from the pilot and transfers the response. Fig A1.3 shows the interior working of ATC.

Fig A1.3 ATC Interior

Courtesy: Reddit r/Pics

The main hardware components that we are going to use are shown in fig A1.4. A good performing Personal computer with internet connectivity and earphones for passing the input.

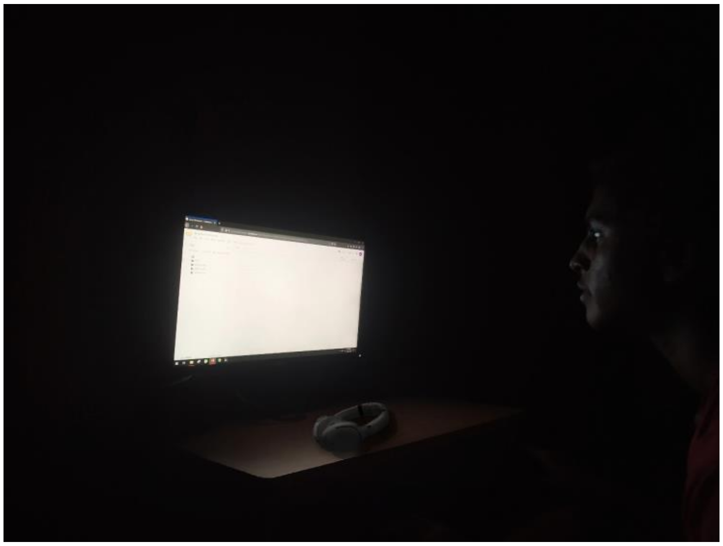

Fig A1.4 PC and earphones

Initially the audio (Speech request) has to be passed as input the system and the system responds after receiving the audio as shown in fig A1.5 and A1.6.

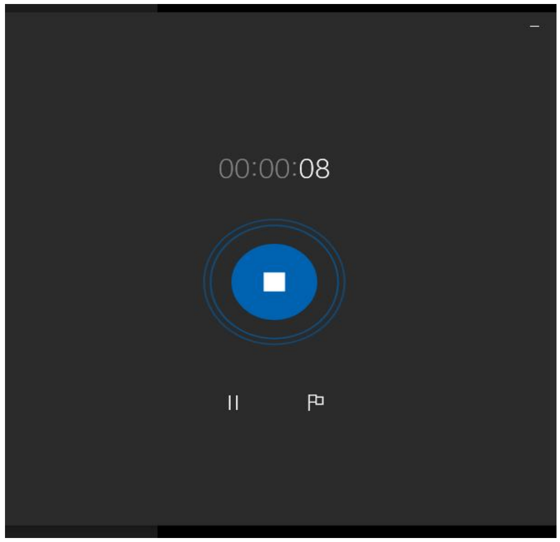

Fig A1.5 Audio input

```
r=sr.Recognizer()
harvard=sr.AudioFile(fn)
with harvard as source:
  audio = r.record(source)
if(audio):
  print("Audio Received Successfully")
else:
  print("Audio Error")
```

```
Audio Received Successfully
```

Fig A1.6 System Response after receiving audio

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. 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. The audio converted to text is shown in the below fig A1.7

```
[7] from google.colab import files
    uploaded= files.upload()

    for fn in uploaded.keys():
      print('User uploaded file "{name}" with length {length} bytes'.format(
          name=fn, length=len(uploaded[fn])))
```

```
Browse... audio_1.wav
audio_1.wav(audio/wav) - 1075278 bytes, last modified: n/a - 100% done
Saving audio_1.wav to audio_1.wav
User uploaded file "audio_1.wav" with length 1075278 bytes
```

```
[8] harvard=sr.AudioFile('audio_1.wav')
    with harvard as source:
      audio = r.record(source)
```

```
audio_text=r.recognize_google(audio)
print(audio_text)
```

```
Air India 101 poling short of Runway ready for takeoff
```

Fig A1.7 Audio converted to text

Figure A1.8 is the screenshot of 2nd module, where the LSTM working takes place.

```
[ ] import nltk
    nltk.download('stopwords')
    nltk.download('punkt')
    from nltk.corpus import stopwords
    from nltk.tokenize import word_tokenize
    stop_words = set(stopwords.words('english'))
    word_tokens = word_tokenize(audio_text)

    filtered_sentence = [w for w in word_tokens if not w in stop_words]

    filtered_sentence = []

    for w in word_tokens:
      if w not in stop_words:
        filtered_sentence.append(w)

    print(word_tokens)
    print(filtered_sentence)
```

```
[nltk_data] Downloading package stopwords to /root/nltk_data...
[nltk_data]   Package stopwords is already up-to-date!
[nltk_data] Downloading package punkt to /root/nltk_data...
[nltk_data]   Package punkt is already up-to-date!
['Air', 'India', '101', 'poling', 'short', 'of', 'Runway', 'ready', 'for', 'takeoff']
['Air', 'India', '101', 'poling', 'short', 'Runway', 'ready', 'takeoff']
```

Fig A1.8 Text Summarization

Figure A1.9 represents the screenshot of generating suitable response from CSV after the summarization takes place.

```
import pandas
with open('response.csv', mode='r') as csv_file:
    csv_reader = csv.reader(csv_file,delimiter=',')
    request=[]
    response=[]
    actual_response=''
    i=0
    for row in csv_reader:
     request.append(str(row[0]))
     response.append(str(row[1]))
    for i in range(len(filtered_sentence)):
      for k in range(len(request)):
          if(filtered_sentence[i]==request[k]):
              actual_response=response[k]
  file = open("airlines.txt",'r')
  tmp=' '
  count=0
  while True:
  count+=1
  line=file.readline().replace('\n','.')
  tmp=line
  if (tmp in audio_text):
    found_flag=1
    print(actual_response+' '+tmp+'101')
Cleared for Takeoff  AirIndia 101
```

__Fig A1.9 Response Generation__

Fig A1.10 shows the audio response.

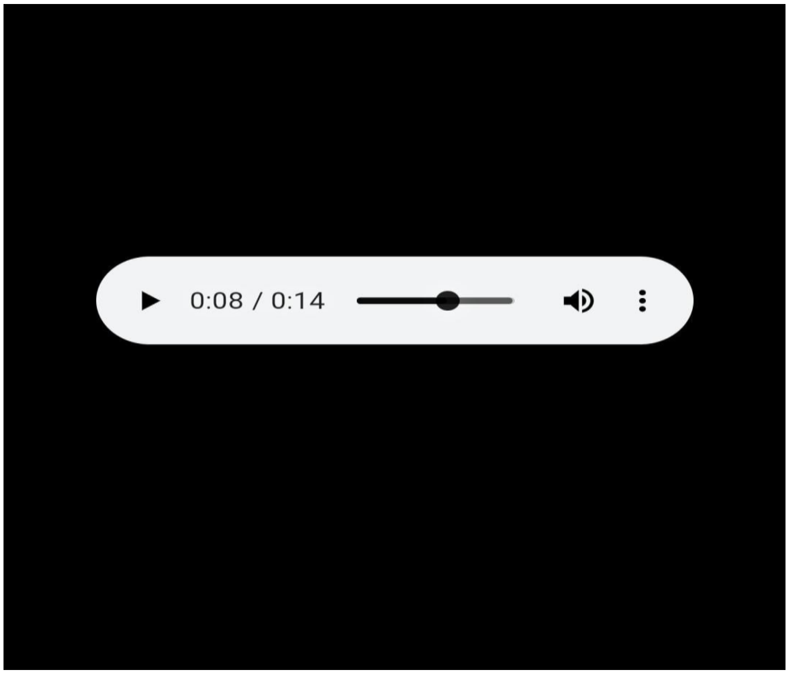

__Fig A1.10 Audio response__

APPENDIX B

SAMPLE CODING

```
pip install SpeechRecognition #Speechrecognition module
pip install google-cloud-speech #GoogleCloudSpeech Module
pip install apiai #another module
pip install nltk
pip install pandas
import speech_recognition as sr
import nltk
import pandas
```

#audio receiver function

```
r=sr.Recognizer()
harvard=sr.AudioFile(fn)
with harvard as source:
audio = r.record(source)
if(audio):
    print("Audio Received Successfully")
else:
    print("Audio Error")
```

#recognizer function for speech2text

```
audio_text=r.recognize_google(audio)
print(audio_text)
```

#tokenization module

```
nltk.download('stopwords')
nltk.download('punkt')
from nltk.corpus import stopwords
from nltk.tokenize import word_tokenize
stop_words = set(stopwords.words('english'))
word_tokens = word_tokenize(audio_text)
filtered_sentence = [w for w in word_tokens if not w in stop_words]
filtered_sentence = []
for w in word_tokens:
    if w not in stop_words:
        filtered_sentence.append(w)
print(word_tokens)
print(filtered_sentence)
```

#end of tokenization module

#response module

```
with open('response.csv', mode='r') as csv_file:
csv_reader = csv.reader(csv_file,delimiter=',')
request=[]
response=[]
actual_response=''
i=0
for row in csv_reader:
request.append(str(row[0]))
response.append(str(row[1]))
for i in range(len(filtered_sentence)):
 for k in range(len(request)):
```

```
if(filtered_sentence[i]==request[k]):
    actual_response=response[k]
file = open("airlines.txt",'r')
tmp=' '
count=0
while True:
count+=1
line=file.readline().replace('\n','.')
tmp=line
if (tmp in audio_text):
        found_flag=1
print(actual_response+' '+tmp+'101')
```

#end of response module

APPENDIX C

SYSTEM REQUIREMENTS

HARDWARE SPECIFICATION

- 4 GB RAM or Higher
- 256 GB Storage or Higher
- Internet Connectivity
- Recording Microphones
- Basic Computer Peripherals

SOFTWARE SPECIFICATION

- Windows 7 or Higher
- Google Colab
- NLTK
- Keras Library
- Google Cloud Speech
- Pandas Library
- NumPy Library
- Speech Recognition Library
- APIAI Library

APPENDIX D

PUBLICATIONS

[1] Kailasa Eswaran I, Balaji C and M Ashok, presented a paper titled "Implementation of LSTM in ATC for Avionics" in the "8^{th} International Conference on Contemporary Engineering and Technology 2020 (ICCET'2020)" organized by Prince Shri Venkateshwara Padmavathy Engineering College on 14^{th} and 15^{th} March 2020.

8th INTERNATIONAL CONFERENCE ON CONTEMPORARY ENGINEERING AND TECHNOLOGY 2020

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PRINCE DR. K. VASUDEVAN COLLEGE OF ENGINEERING & TECHNOLOGY

(Approved By All India Council For Technical Education, Affiliated To Anna University)

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Certificate of Presentation

This is to certify that KAILASA ESWARAN . I *from* RAJALAKSHMI INSTITUTE OF TECHNOLOGY *has presented a paper titled* IMPLEMENTATION OF LSTM IN ATC FOR AVIONICS *in the "8th International Conference on Contemporary Engineering and Technology 2020" held on 14th & 15th March 2020.*

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327.IMPLEMENTATION OF LSTM IN ATC FOR AVIONICS

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Air traffic control is one of the most stressful job as it requires high level human intervention, concentration and dynamic decision making. So ATC is the least automated field in aviation due to challenges faced in voice recognition and transmission. Our idea mainly uses call sign detection and text to speech conversion by using LSTM to instruct the pilot for handling the flight. The LSTM model is fed with inputs from flight plan and is compared with the dataset and required output will be predicted. The major drawback will be, noisy communication channel, that leads to poor voice recognition. Our project uses long short term memory of recurrent neural networks for text related processing of data and also aims in building an effective voice recognition server.

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