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An Intelligent Air Traffic Control System using Fuzzy Logic Model

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ABSTRACT

The application of fuzzy logic in solving flight schedule and air traffic control problems. Fuzzy set theory is appropriate in dealing with this problem because of its ability to deal with control operations and the development of knowledge-based systems using approximate reasoning. The objective is to solve the problem inherent with poor traffic control using an intelligent (knowledge-based) system based on learnt procedures and processes over a set period of time. A fuzzy logic model for air traffic control system is developed that will enhance the performance of air traffic controller and reduce the rate of aircraft accident. The Object-Oriented Analysis and Design Methodology (OOADM) is used in designing the intelligent air traffic control system proposed in this paper. A fuzzification block is designed to convert the fuzzy logic controller. The fuzzy logic input values used are Pathway, Velocity, Climate, Airplane, Height and D-term - which allows the controller to respond faster to permission for clearance. Eleven rules were constructed based on the assigning of linguistic values defined by relatively small number of membership function to variable. The computation block runs the inference engine through all the rules, evaluating the firing strength of each rule whose result is proportional to the truth-value of the preconditions. MATLAB was used to simulate the outcome. The Nigeria airspace is used in the study. From simulated results, safety rules projected were observed by all aircrafts with absolute control irrespective of the number of aircrafts demanding service at a particular time interval. Air accidents were perfectly avoided.

General Terms:

Fuzzy Logic, Air-Traffic Control

Keywords

Fuzzy logic, Intelligent system, Air-traffic control, Knowledge-based systems, OOADM

1. INTRODUCTION

Fuzzy logic is derived from fuzzy set theory. Fuzzy logic deals with approximate rather than precise reasoning. However, rough practical answers can result to be more effective in other cases than complex precision. Fuzzy logic was developed for control operations to develop knowledge-based systems and allows values to be defined like true/false and yes/no. It is simple to implement and hence it is becoming more favorite for knowledge-based system implementations. It can be used where the traditional controllers like proportional integration (PI) controllers are in use. These controllers use linear control action while fuzzy logic provides controlling action with fuzzy set and rules. Conventional controllers depend on mathematical modeling while fuzzy controller depends on information provided by membership functions from domain experts. Fuzzy logic controllers (FLCs) are rule-based systems which are applicable to poorly understood nonlinear systems, occasionally controlled by human operators without knowledge of their underlying dynamics. Air Traffic Control Service (ATCS), presently referred to as Air Traffic Management (ATM) is one of the most important services provided by air traffic control agencies. Air Traffic Control (ATC) is divided into the several departments as follows: Operations, Standards, Airspace Planning, Technical Evaluation, Search and Rescue Civil/Military Coordination [12, 11]. These services are anchored towards the realization of the mission of the Air Transport Agency(ATA) with regards safety, efficiency and economy in air navigation service provisions. The ATCS provides a direct medium through which the major customers of the ATA i.e., Aircraft operators, can access and rate the quality of services being provided.

ATCS services are provided to prevent collisions of aircraft on the maneuvering area, between aircraft and obstructions, and to expedite and maintain an orderly flow of air traffic. Air Traffic Control Service is an old concept introduced with air transport in Nigeria. The department is headed by the General Manager (ATC Operations) at the headquarters, and at station, by the Air Traffic Operations Manager simply referred to as ATOM. ATCS services are provided by Air Traffic Controllers in all the nations airports. The service is provided by different units depending on the type of airspace under the control of each unit. ATM is the dynamic, integrated management of air traffic and airspace including Airspace Management, Air Traffic Flow Management and Air Traffic Services aimed at the provision of facilities and seamless services in collaboration with all parties and involving airborne and ground-based functions to enhance safety, economy and efficiency.

ATCS is sub-divided into approach control service, area control service, and aerodrome control service. A unit is established to carry out each of these services. Aerodrome and approach control services are combined in many airports at the aerodrome control unit, but are separated in Lagos, Abuja and Port Harcourt airports. Air Traffic Control Services are provided either with procedural (non-radar) control or radar. There are four stations in Nigeria where radar is used for the provision of ATCS. These stations are Abuja, Kano, Lagos, and Port Harcourt. The whole Nigerian airspace is however covered by Total Radar Coverage of Nigeria (TRACON). The provision of Area Radar Control will soon commence within the Nigerian Airspace. In recent time, it has been reported that Nigerian airports communication and surveillance equipment are less than the standard due to the nationals airports poor facilities.

This paper presents an Intelligent Flight Control System (IFCS) using fuzzy logic model as a next-generation tool for flight control system designed and enabled to provide increased safety for aircraft occupants - the crew and passengers - and the optimization of the aircraft performance under normal conditions. The main benefit of this system is that it allows a pilot to control an aircraft even under failure conditions that would normally cause it to crash.

In this work we discuss the implementation of an intelligent air traffic control system using fuzzy logic model/technology which has the capability of mimicking human intelligence for controlling traffic. The rules and membership functions of the fuzzy logic controller can be selected and changed and their outputs can be compared in terms of several different representations. Fuzzy logic technology allows the implementation of real-life rules similar to the way humans would think. The beauty of fuzzy logic is that it allows fuzzy terms and conditions such as *heavy*, *less*, and *longer* to be quantized and understood by the computer. Fuzzy control is a control method based on fuzzy logic. Fuzzy logic can be described simply as “computing with words rather than numbers” or “working with sentences rather than equations”. A fuzzy controller can include empirical rules, and that is especially useful in operator controlled plants. The collection of rules is called a rule base. The rules are in “IF-THEN” format, and formally the “if” side is called the condition and the “then” side is called the conclusion. The system is able to execute the rules and compute a control signal depending on the measured input, error and change in error [4]. The major building block of an FLC system is fuzzy rule base (RB) related through an inference engine by means of a fuzzy implication and compositional procedure. The RB is normally formulated in linguistic terms, in the form of *if. . . then* rules, and there are various techniques for deriving them. Generally, the correct choice of membership functions for the linguistic variable plays a significant role in the performance of an FLC within the chosen universe of discourse, by providing perfect representation of the expert’s knowledge through robust linguistic control rules.

2. CONCEPT OF AIR TRAFFIC CONTROL

The Air traffic control service is a generic term used for flight information, alerting, air traffic advisory and air traffic control services. The air traffic control system consist of a network of people and equipment employed in safe operation of commercial and private aircrafts. Air traffic controllers also coordinate air traffic movement to ensure that planes stay a safe distance apart. The main concern of air traffic controllers is safety which involves directing planes efficiently to minimize delays. ATC is aimed at removing queuing delays experienced daily during arrival rushes, resulting from en route and terminal airspace congestion [14]. According to [15] delay is categorized into en route (in flight) delay, gate delay, taxi-out delay, terminal delay and taxi-in delay. Each category of delay becomes manifest when the aircraft attempts to requires more time in that regime than was scheduled. Delay in airport has significant environmental impact in particular that of noise exposure on the community where the airport is located [3].

2.1 Use of a Flight Progress Strips in Aerodrome and Approach Control

The procedures for the marking of standard flight progress strips as used in Aerodrome and Approach Control. Strips are used as follows:

a. Departing flights is labeled as Form AD30A and the colour of cardboard paper used for the form is blue.
b. Arriving flights - is labeled as Form AD20D and the colour of cardboard paper used for the form is buff.
c. Local flights - is labeled as Form DCA30 and the colour of cardboard paper used for the form is pink.

2.1.1 Strip Marking For Departing Flights. **Instrument Flight Rule (IFR) Plans:**
Figure 1 below shows the strip marking for departing flights.
Box A. Vacant or aerodrome abbreviation if the departure is from a subsidiary airfield

Box B. Planned cruising level.

Box C. Estimated time of departure.

Box D. Actual time of departure.

Box E. May be used to note the time at which an aircraft sets course.

Box F. (i) Aircraft identification in large printing in the centre.
(ii) Aircraft type in top right-hand corner.
(iii) Planned cruising true airspace in bottom right-hand corner.
(iv) Planned initial climbing true airspace in bottom left-hand corner (if required).

Box G. The time at which action is initiated to contact the Air Traffic Control Centre (ACC) for a clearance.

Box H. Time at which clearance is issued by ACC. If the aircraft is turbine powered, the box is divided into halves by drawing a diagonal line from the top right to the lower left hand corner and the time at which start-up clearance is issued is written in the upper half of the box, the time at which Air Traffic Control (ATC) clearance is issued is written in the lower half.

Box I. The time at which any revised clearance is received.

Box J. Planned route and destination.

Box K. Full details of the clearance written verbatim in abbreviated form omitting aircraft call-sign, type, airfield of departure and general routeing.
Box L. Full details of any revised clearance. A diagonal line being drawn through the cancelled clearance Box K.

Box M. Domestic use (Details of transfer of control, position reports etc)

A check mark will be made against the clearance in Box K or the revision in L when it has been transmitted to the aircraft and acknowledged.

2.1.2 Visual Flight Rule (VFR) Plans. Strip marking as in Figure 2 above with the following exceptions. Box B implies VFR inserted, Boxes G, H and I as well as K and L are not used.

2.1.3 Strip Marking for Arriving Flights Instrument Flight Rule (IFR) Plans. Box A. (i) Clearance limit in top right- hand corner. (ii) Estimated Time of Arrival at clearance limit-hours in large numerals and minutes in small.

Box B. Time of arrival over the clearance limit. Whenever the aircraft is required to hold over the clearance limit facility the Box is divided into two equal portions by a diagonal line ending in the bottom left-hand corner, the time of arrival over the position is entered in the lower left portion and the time of leaving in the upper right portion.

Box C. (i) Level information in the vertical column stating at the top left corner. The first entry is the release levels, entries below show the levels down to which the aircraft is later cleared. If reports from the aircraft through any of the intervening levels are required, these levels are listed in descending order and cancelled by horizontal lines as reports are made. An arrow indicating descent is drawn and subsequently cancelled after the aircraft reports its arrival at the new level, or passing through the level immediately above.
(ii) If an aircraft cancels its IFR plan VFR in large letters is inserted in the box.

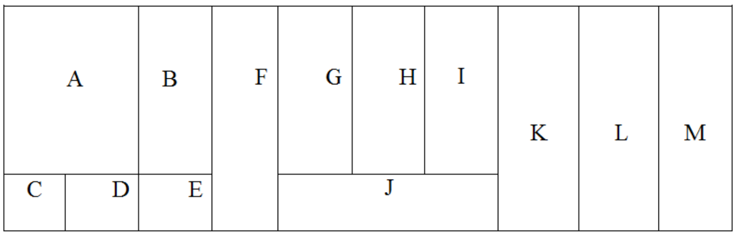


Fig. 1. Strip Marking for Departing Flights

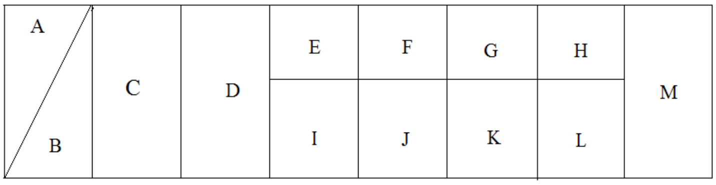


Fig. 2. Strip Marking for Arriving Flights

Box D. (i) The aircrafts identification or radio call-sign in large outline near the centre of the Box. (ii) The type of aircraft at the top right-hand corner.
(iii) The aerodrome of departure in the top left-hand corner.

Box E. Flight plan for estimated time of arrival.

Box F. Actual time of landing.

Box G. Vacant.

Box H. Vacant.

Box I. Landing Aerodrome Abbreviation (if subsidiary).

Box J. Release Point.

Box K. Expected approach time.

Box L. The contact point;
(i) If this is a position, the abbreviation is written at the top of the Box and the time over the facility inserted below. (ii) If it is a level or a time, the Box is check-marked when communication is established.

Box M. Domestic use (Type of approach aid, co-ordination with other aerodromes etc.).

Strip marking as in Figure 3 above with the following exceptions: Box A for ETA aerodrome only; Box B Vacant; Box C Large VFR inserted; Boxes G,H,I,J,K, and L Vacant.
The pink strip will only be used for local VFR flights, or local IFR flights remaining under the control of Aerodrome or Approach Control. Owing to the varying requirements at aerodromes, the type of flight etc., as much room as possible is left for domestic use.

Box A. (i) Clearance limit in the top right-hand corner. (ii) ETA at the clearance limit.

Box B. Actual time of arrival at the clearance limit.

Box C. Level or VFR.

Box D. Aircraft identification.

Box E. Estimated time of departure.

Box F. Actual time of arrival.

Box J. Actual time of departure.

Boxes G, H, J, K, Land M. Flight details/domestic use.

2.1.4 Strip Marking. Flight progress strip marking is done using ball point pens colours(Figure 4).
All entries made on flight progress strips by assistant controllers or clerks were made in black.
All entries made on flight strips by air traffic control officers are made in red.
All entries made on flight progress strips by supervisors are made in green.
Block capitals is used for all lettering.
Corrections or revisions to data are made by striking through the original entry and writing the up to date information alongside in the same box.
Strip Marking for En Route Flight Progress Strips:
Box A. (i) ATC estimate of the time an aircraft is expected to reach a reporting point: the hour being written in larger figures than the minutes. All subsequent time entries in other boxes on the same strip need only be the minutes figures unless the hour varies from the hour shown in this box when the full figure group must be entered. (ii) The abbreviation for the reporting point to which the strip refers is put in the top right hand corner.

Box B. (i) the time of the aircraft's arrival over the reporting point. (ii) If the aircraft will hold in flight over this point, the box is divided into halves by drawing a diagonal line into the lower right hand corner. The arrival time being entered in the lower half and the time of leaving the reporting point in the upper half.

Box C. Flight level information in hundreds of feet. If the cleared and actual levels over a point differ, the actual figure is entered and encircled. No marking is required when the values are the same.
When different levels are assigned to successive reporting points, the level at which the first point is crossed is written in the upper right hand corner of this box on the next strip and enclosed in a square. In assigning a level, this level together

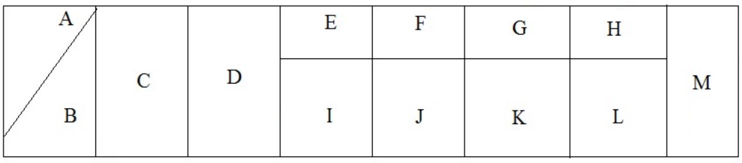


Fig. 3. Strip Marking for Local Flights

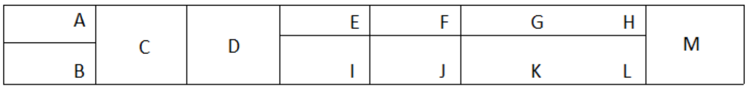


Fig. 4. Strip Marking for En Route Flight Progress Strips

with all intermediate levels for which reports are required are entered in sequence and a climb or descent arrow is written between the initial and the final levels. Upon report of leaving or passing through a level, the figures are cancelled through with a horizontal line. Upon report of reaching the assigned level the climb or descent arrow is cancelled through. Visual Flight Rule (VFR) in the large letters across the box to denote that the aircraft has cancelled its IFR plan.

Box D. (i) Aircraft identification in large outline in the centre of the box. (ii) The standard abbreviation for the type of aircraft in the upper right-hand corner. (iii) Ground speed of the aircraft and preceded by a “T” the filed true airspeed, in the lower right-hand corner. (iv) On the final strip for an arriving aircraft the abbreviation for the place of departure in the upper left-hand corner.

Box E. Joining symbol,Leaving symbol,Crossing symbol, if appropriate.

Box F. Time of arrival if required.

Box G. Pilot’s estimate of arrival over the reporting point.

Box H. (i) Actual time, of arrival over the previous reporting point. (ii) The abbreviation for the previous reporting point if necessary for clarity.

Boxes I, J, K. (i) The route of flight showing departure and destination aerodrome and the Airways and Advisory Routes to be flown: the Airways abbreviations can be taken to include associated Advisory routes. It is necessary to write the Advisory Route numbers only when there are no associated Airways. (ii) On the final strip for an arriving flight Box I is used for the destination aerodrome where more than one aerodrome is fed from a common stack.

Box J. For the release point to Approach Control and Box K for the Expected Approach Time.

Box L. (i) The time place or level at which the aircraft is instructed to contact the next ACC. (ii) The frequency to M is used, but only when it is non-standard.

Box M. Control data which has been passed to aircraft such as essential traffic information, holding instructions, time check.

2.1.5 Departure Flight Progress Strips. The strip in Figure 5 is used for departure flights by the ACC.
Box A. Aerodrome of departure

Box B. Cruising level requested by pilot.

Box C. Estimated Time of Departure.

Box D. Actual Time of Departure.

Box E. May be used to note the time at which an aircraft sets course.

Box F. Aircraft identification in large outline in the centre of the box. The type of aircraft in the upper right hand corner. Filed True Air Speed (TAS) in the bottom right hand corner.

Box G. Time at which clearance is requested.

Box H. Time at which clearance is issued. If the aircraft is turbine powered, the box is divided into halves by drawing a diagonal line from the top right to the lower left hand corner and the time at which start-up clearance is issued is written in the upper half of the box, the time at which ATC clearance is issued is written in the lower half.

Box I. Any delay anticipated by the outbound control officer when clearance is requested.

Box J. Proposed route of aircraft.

Box K. Initial clearance showing details of zone routeing and levels, cruising level, radar climb, restrictions to take-off.

Box L. Any revised clearances issued and M.

3. FUNCTIONS OF AIR TRAFFIC CONTROL SYSTEM

Air traffic controller performs the functions of air traffic control system; some regulate airport traffic through designated airspaces. Others regulate airport arrivals and departures. The functions of air traffic control system as enumerated by International Civil Aviation Authority (ICAA) are Area control, Approach control and Aerodrome control [9].

The separation between all IFR flights and between IFR flights and VFR flights is done in the Area Control system. Aircraft is expected to be equipped with navigation and suitable instrument appropriate for the route to be flown. Specification of minimum level necessary for takeoff or landing is specifically authorized by the appropriate authority. An IFR flight is flown at a level which is not below the minimum flight altitude established by the authority whose territory is over flown. Where no such minimum flight altitude has been established, over high terrain or in mountainous areas, at a level which is at least 600m (2000ft)

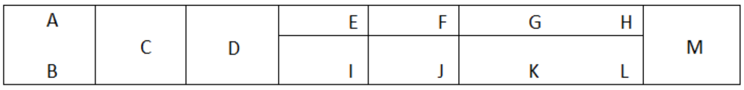


Fig. 5. Strip Marking for Departure Flight Progress Strips

above the highest obstacle located within 8km of the estimated position of the aircraft. Also elsewhere than as specified above at a level which is at least 300m (1000ft) above the highest obstacle located within 8km of the estimated position of the aircraft. It is possible to change from IFR Flight to VFR Flight.
VFR flight is conducted such that aircraft flies in condition of visibility and distance from cloud equal to or greater than those specified only when a clearance is obtained from air traffic control unit. VFR flight is restricted to take off or land at an aerodrome within a control zone, or entrance into the aerodrome traffic zone or traffic pattern based on the following rules:
i. The ceiling being less than 450m (1500ft) or

ii. The ground visibility being less than 5km.

A general rule for VFR flight between sunset and sunrise, or such other period between sunset and sunrise as may be prescribed by the appropriate Air Traffic Service (ATS) authority is operated in accordance with the condition prescribed by such authority. In Nigeria, no VFR is allowed between sunset and sunrise.
Also, unless authorized by the appropriate ATS authority, VFR flight is not operated (i.) above flight level (FL) 200 and (ii.) at transonic and supersonic speeds.

As part of safety precautions, except for exceptional take-off or landing, or by permission from the appropriate authority, a VFR flight is not flown:
i. over a congested area - cities, town or settlements or an open-air assembly of person - at height, less than 300m (1000ft) above the highest obstacle within a radius of 600m (2000ft) from the aircraft;

ii. elsewhere at a height less than 150m (500ft) above ground or water level.

The Nigerian Aviation Authority allows a VFR at a height not less than 300m (1000ft) above the highest obstacle within a radius of 600m (2000ft). Every VFR flight operating within or into areas, or along route designated by the appropriate ATS authority in accordance with requirement to submit a flight plan, shall maintain continuous listening watch on the appropriate radio frequency, and report its positions as necessary to air traffic services unit providing flight information services. An aircraft operated in accordance with the VFR which wishes to change to compliance with the IFR shall, if a flight plan was submitted, communicate the necessary changes to be effected to its current flight plan or, when so required, submit a flight plan to the appropriate air traffic services unit and obtain a clearance prior to proceeding IFR.

4. NAVIGATIONAL AIDS EQUIPMENTS FOR INSTRUMENT FLIGHT RULES

Navigational aids equipment used for Instrument Flight Rules include Non Directional Beacon (NDB), Very High Omnidirectional Range/Instrument Landing system (VOR/ILS), Radio Detection And Ranging (RADAR), etc. RADAR is one of the electronic navigation aids. RADAR is unique, and provides the air traffic controller with a comprehensive view of air traffic over a wide area. This makes it assume a crucial role in ATC procedures, especially in busy airspace and particularly under positive control. ATC RADAR must have the capability of carrying out the functions and roles of (i.) approach control, (ii.) extended approach control, and (iii.) terminal area control, with the added capability of extended range using Secondary Surveillance RADAR (SSR) techniques.
RADAR systems is capable of integrating with other automated systems used in the provision of Air Traffic Service (ATS). It provides an appropriate level of automation with the objectives of improving the accuracy and timeliness of data displayed to the controller, and thereby, reduce the workload of the controller and the need for verbal coordination between adjacent control positions and ATC units, [10].
RADAR systems is capable of displaying safety-related alerts and warnings, including conflict alerts, minimum safe altitude warning, conflict prediction and unintentionally duplicated codes. To extend and improve RADAR coverage in adjacent control areas, airports throughout the federation through their state authorities should, as much as possible, facilitate the sharing of information. States should, on the basis of regional air navigation agreements, provide for the automated exchange of coordination data relevant to aircraft being provided with radar services, and establish automated coordination procedures. Primary Surveillance Radar (PSR) and Secondary Surveillance Radar (SSR) are used either alone or in combination in the provision of ATS, for separation between aircraft.

4.1 Radar Displays

Radar-derived data available for display to the controller include the following: Radar position indications, Radar map information SSR Mode A, Mode C and Mode S. The RADAR system provides for a continuously updated presentation of RADAR derived information and RADAR position indications.

4.1.1 Radar Vectoring. Radar vectoring is the provision of navigation guidance to aircraft in the form of specific headings, based on the Radar in use. When vectoring an aircraft, a Radar controller should comply with the following:

a. Vector along routes or tracks on which the pilot can monitor the aircraft's position with reference to pilot-interpreted navigation aids. This minimizes the amount of Radar navigation assistance required and also alleviates the consequences resulting from a radar failure.
b. Inform the pilot when his aircraft is given a vector, diverting it from an assigned route, unless it is self-evident what the vector is to accomplish.
c. Controlled flights are not vectored into uncontrolled airspace except in an emergency case to circumnavigate severe weather, in which case the pilot should be so informed at the specific request of the pilot.
d. When vectoring an IFR flight, the radar controller should issue clearances such that the prescribed obstacle clearance will exist at all times until the aircraft reaches the point where the pilot will resume own navigation.

4.2 Rules Guiding Aircraft in Flight and on Ground

In order to ensure safe and efficient movement of flight both in air and on ground, recommended rules have been made to facilitate this. For instance aircraft are made to fly in specified direction called route. This route could either be international route or domestic route. The international routes are those routes that are internationally recognized and endorsed by International Civil Aviation Organisation (ICAO) while the domestic routes are those routes known only within the air space of the country that uses it. Examples of such routes are:

i. UR/R 778 extending from Lagos through Kano and exit into Niger at a point called GANLA to North Africa or Asia.

ii. UR/R 981 extending from Lagos through an exit in Nigeria called TENTU to Europe.

In Nigeria, domestic routes are those routes approved by Nigerian Air Space Management Agency linking towns and states. Such route is used to ease traffic movement in our air space. An example is UV 377 extending from Lagos to Kaduna etc. In moving along this route, aircraft are made to move on certain height above sea level, called flight level (FL). The flight level is designed in such a way that aircraft moving along a designated route either *West-Ward* or *East-Ward* occupy a specified level. In order to avoid collision hazard, aircraft moving east-ward occupy odd level (odd number) and even level (even number) for west-ward. Thus, by using progress strip for each aircraft, safety can be achieved to certain extent. It is the duty of air traffic controller to assigning this level at the request of the pilot of an aircraft.

4.2.1 Separation Standards and Collision Avoidance. ATC is responsible for separation between aircraft and collision avoidance. Provision of separation is between:

i. all flights in class A and B airspaces
ii. IFR flights in class C,D and E airspaces
iii. IFR and VFR in class C airspace
iv. IFR and special VFR flights
v. special VFR flights, when prescribed by ATS authority

And to increase separation in navigational difficulties, weather avoidance or turbulence and unlawful interference. Then reduce separation determined by the appropriate ATS authorities are as follows:

1. When special electronic or other aids enable pilot to accurately determine aircraft position, and communications facility exist for that position to be transmitted without delay to appropriate Air traffic Control Unit (ACCU), or when using rapid and reliable communication facilities, RADAR-derived information of aircraft position is available to ACCU, or determined by the appropriate ATS authority, or when special electronic or other aids enable ATC to predict rapidly and accurately the flight paths of aircraft and adequate facilities exist to frequently verify the actual aircraft positions with the predicted positions; or when navigational (NAV)-equipped aircraft operate within coverage of electronic aids that provide the necessary updates to maintain navigational accuracy.

2. According to regional air navigation agreements; when special electronic, area navigation or other aids enable the aircraft to closely adhere to their current flight plans and the air traffic situation is such that the conditions as determined by ATS authority regarding communications between pilots and the appropriate ACCU need not necessarily be met to the degree specified therein Pilot tells ATC that they cannot comply as a result of degraded aircraft performance, then ATC will ensure separation of another appropriate type. Types of Separation: There are two types of separation, Vertical and Horizontal separation.
i. Vertical Separation is obtained by requiring aircraft using prescribed altimeter setting procedures to operate at different levels expressed in terms of flight levels or altitudes. It is carried out above or below flight level 29,000 ft.
ii. Horizontal Separation is subdivided into Lateral, Longitudinal and Radar separation. Lateral separation of aircraft at the same level is obtained by requiring flight on different routes or in different geographical locations as determined by visual observation or by use of radio navigation aids.
Longitudinal separation is applied such that after one aircraft passes over a specified position, the next succeeding aircraft at the same cruising level will not arrive over the same position within less than the prescribed minima. Radar separation is obtained by requiring aircraft to fly on different tracks which can accurately be determined by reference to a Radar display.

4.2.2 Flight Action. Before beginning a flight, the pilot-in-command of an aircraft shall become familiar with all available information appropriate to the intended operation (Muhammed, 2006). Pre - Flight action for flights away from the vicinity of an aerodrome, and for all IFR flights, pilot shall fill flight plan after careful study of available current weather reports and forecast, taking into consideration fuel requirements and an alternative course of action if the flight cannot be completed as planned. Based on this, a progress flight strip is manually created by Air Traffic Controller for the aircraft.

i. Authority of Pilot-in-command of an aircraft:
The pilot-in-command of an aircraft shall have final authority as to the disposition of the aircraft while in charge.

ii. Avoidance of Collisions:
Although the pilot of an aircraft operates under the instruction of a positive control of an Air traffic controller, never the less, there are certain portion of the rules that requires the pilot to use his discretion, where the pilot feels such instructions could cause collision hazard to his flight, irrespective of the fact that the flight is being made with ATC clearance, it shall remain the duty of the commander (pilot in charge) of an aircraft to take all possible measures to ensure that his aircraft does not collide with any other aircraft.

iii. Right - of - Way:
The aircraft that has right of way shall maintain its heading and speed, but nothing in the rules shall relieve the pilot-in-charge of an aircraft from the responsibility of taking such action best to avert collision. An aircraft that is obliged by the following rules to keep out of the way of another shall avoid passing over, under or in front of the other, unless it passes well clear and takes into account the effect of aircraft wake turbulence.

iv. Approaching Head-on:
When two aircraft are approaching head - on or approximately so and there is danger of collision, each shall alter/turn its head to the right [2].

v. Aircraft Converging:
When two aircrafts are converging at approximately the same level, the aircraft that has the other at the right side shall give way.

vi Overtaking Aircraft: An aircraft that is being overtaken has the right-of-way and the overtaking aircraft, whether climbing, descending or in horizontal flight, shall keep out of the way of the other aircraft by altering its heading to the right.

vii. Aircraft Landing:
An aircraft in flight or operating on the ground or water shall give way to aircraft landing or in the final stages of an approach to land. When two or more aircrafts are approaching an aerodrome for the purpose of landing, aircraft at the higher level shall give way to aircraft at the lower level. However such aircraft should take cognizance of the aircraft that is about landing.

vii. Emergency Landing:
An aircraft that is aware that another is compelled to land shall give way to that aircraft.

viii. Aircraft Taking Off:
An Aircraft taxing on the maneuvering area of an aerodrome shall give way to aircraft taking off or about to take off.

4.2.3 Surface Movement of Aircraft. In case of danger of collision between two aircraft taxing on the movement area of an aerodrome the rules shall apply that when two aircrafts are approaching head-on, or approximately so, each shall stop or where practicable alter its course to the right so as to keep well clear, if the stipulated rules are adhered to strictly. Analyzing the various accidents critically indicate that most of the accidents that had occurred to date show that the accidents happen either at the point of take-off, after take-off, about landing or after landing on the runway. However that does not mean that accidents don't happen mid-air in flight or even on the surface movement of the aerodrome. An example of such accident on the surface is between two aircrafts, Boeing 747, operated by KLM and Panam, collided on a Foggy runway killing 583 people in March 1977. (The leadership weekend No. 39 Nov. 4th 2006). Also a mid-air accident due to human errors occurred between an Ilyushin (IL - 76) cargo jet from Kazakhstan and with Saudi Air B747 near New Delhi killing 349 in November 1996. (The leadership Weekend No. 39 Nov. 4th 2006). Investigation shows that the Kazakh crew disobeyed instructions and neither plane was equipped with collision avoidance technology [13]. When two aircrafts are on a converging course, the one which has the other on its right shall give way by slowing down or stopping. Thus, having examined the various rules guiding aircraft in flight and on the surface movement, it could appear at this juncture that the human error that is much talked about could be averted because many people have lost their life as a result of inherent limitation of current navigation systems and shortcoming of controllers. In Nigeria alone thousands have died as a result of plane crash (Nigerian College of Aviation Technology, Zaria Library Compilation, (2007)).

5. THE ARCHITECTURE FOR THE PROPOSED SYSTEM

The proposed fuzzy model(design) for air traffic control is presented in the block diagram. The fuzzification block converts the fuzzy logic controller. The design uses input values such as *pathway*, *velocity*, *climate*, *airplane*, *height* and *D-term* to allow the controller respond faster to *permission* for clearance. Eleven rules were constructed based on the assigning of linguistic values defined by the membership function. The computation block runs the inference engine through all the rules, evaluating the firing strength of each rule which is proportional to the truth-value of the preconditions. After all the rules are computed, we have the firing strength of each rule, then the defuzzification block to receive as input, the membership values of the outputs or otherwise, the fuzzy outputs as *Clearance*. Then, it returns the actual numerical output which may be ATC output as well as *Clearance* - defined by (*DontClear*, *SemiClear*, *RiskClear* and *Clear*). The components of the system architecture are shown in Figure 6.

6. EXPERIMENTAL RESULTS

Several runs were made with varied values of the fuzzy variables. From the simulation results obtained various simulated values were obtained to determine flight decisions. The first simulation results yields the value for AirPlane as 0.223, Pathway = 0.247 and Climate (weather) = 0.500. The simulation result gave a clearance value of 0.102 as indicated with the deffuzification triangular member function (Figure 7(a)) implying a DontPermit status. An outright DON'T PERMIT implies greater risk of a possible danger permitting the aircraft to takeoff. The clearance value is so low to permit takeoff. Landing might also be a problem in this case

A subsequent run gave the following simulation result values: Airplane = 0.343, Pathway = 0.223 and weather = 0.608, with a clearance value of 0.465 (Figure 7(b)). The result implies a RiskPermit status. The implication here is that permitting any aircraft to land or take off at this point is risky. Various reasons are responsible for this restriction. Firstly, the aircraft size is of a little bigger, although still in the category of small aircrafts and so cannot be permitted. Secondly, the pathway is not large for the aircraft.

Parameter value change resulted in obtaining the Great Permit status. The values are: AirPlane = 0.235, Pathway = 0.801 and climate = 0.837. The simulation result gave a clearance value of 0.733 as indicated with the deffuzification triangular member function (Figure 7(c)). This implies GreatPermit.

From a subsequent simulation result, the value for AirPlane obtained is 0.307, Pathway is 0.633 and Climate is 0.645. The simulation result gave a permission clearance value of 0.558 as indicated with the deffuzification triangular member function (Figure 7(d)). This implies SemiPermit - meaning that permission for takeoff might be granted but with caution - the pathway is lengthy.

The last simulation result produced the following values: AirPlane = 0.247, Pathway = 0.753, Climate = 0.620. The simulation result gave a permission value of 0.502 as indicated with the deffuzification triangular member function (Figure 7(e)). This implies Clear to permit landing as pathway is engaged. The climate value is good for landing and takeoff, but the pathway is engaged and must be cleared before landing or takeoff. Observe that the values for the Pathway parameter in this case and that of GreatPermit statuses are higher than other simulation results. In the GreatPermit status, the pathway is NOT engaged and so the aircraft is permitted to land or takeoff.

7. CONCLUSION AND FURTHER RESEARCH

Air Traffic Control (ATC) is a service provided by ground-based controllers who direct aircraft on the ground and through controlled airspace, and can provide advisory services to aircraft in non-controlled airspace. This paper presented a fuzzy logic model for air traffic control system to enhance the performance of air traffic controller thereby reducing the rate of aircraft accident. The model works by determining the altitude of aircraft, with the consideration of other fuzzy variables, expedite and maintain an orderly flow of air traffic. The designed model also provides necessary safety and precautionary information and support to pilots. It keeps track of multiple targets (aircraft) in clutter and also maintain a record of their identities at the same time. The system employs a lot of complex features aimed at resolving air traffic conflicts.

The new global concept of communication, navigation and surveillance is satellite based. Using satellite capability, which include video transmission, data and voice communication which is ideal for point-to-multipoint, large distribution and simultaneous delivery of data to unlimited number of stations in air traffic management system. Modern aircraft is expected to have IP address with all the navigational aids equipments installed. Aircraft as well as Air Traffic Controller should be networked and thereby making communication between pilot and ATC easier, not only in voice communication but also in the use of intelligent fuzzy model. Further research should aim at using current information and technology communication trends to advance security features of the aircraft and enhance aircraft-to-ADC communication. With the introduction of satellite monitoring device, tracking of aircrafts from takeoff to landing should no longer be a challenge in the air transport industry.

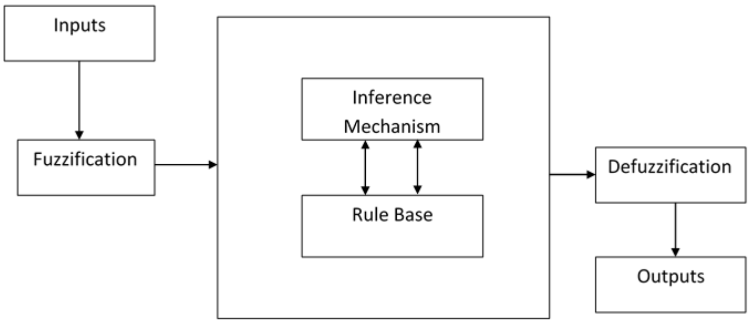
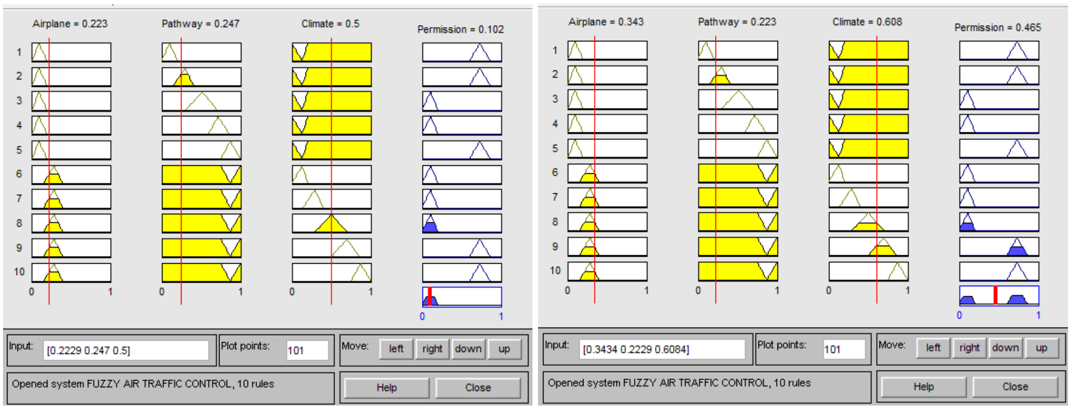


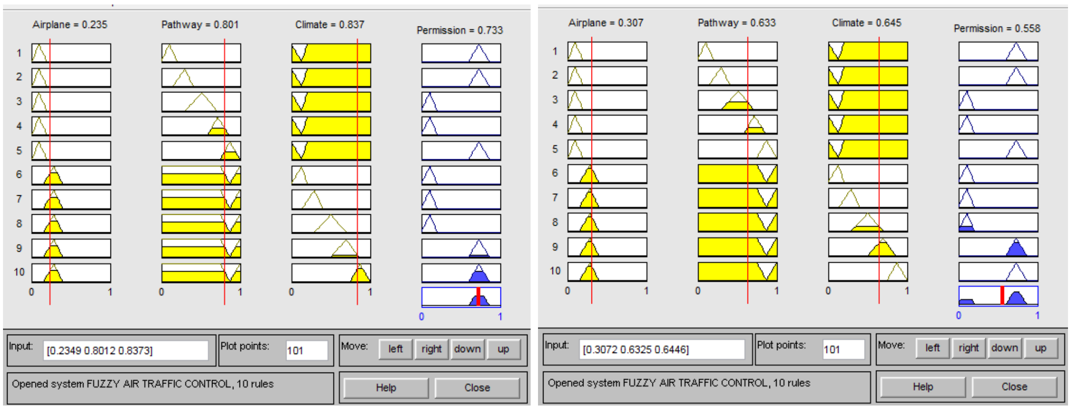
Fig. 6. A block diagram of fuzzy expert system for the proposed system



Input: [0.2229 0.247 0.5] Plot points: 101
Opened system FUZZY AIR TRAFFIC CONTROL, 10 rules

Input: [0.3434 0.2229 0.6084] Plot points: 101
Opened system FUZZY AIR TRAFFIC CONTROL, 10 rules

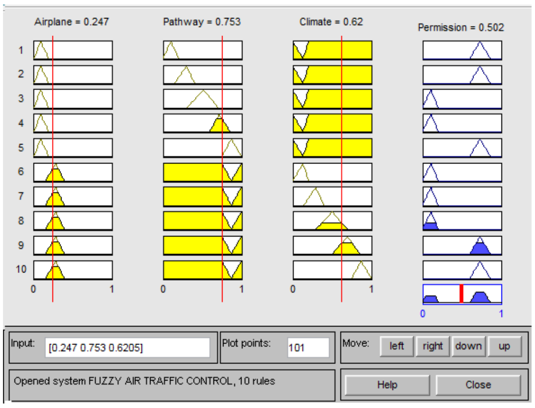
(a) DontPermit (b) RiskPermit



Input: [0.2349 0.8012 0.8373] Plot points: 101
Opened system FUZZY AIR TRAFFIC CONTROL, 10 rules

Input: [0.3072 0.6325 0.6446] Plot points: 101
Opened system FUZZY AIR TRAFFIC CONTROL, 10 rules

(c) GreatPermit (d) SemiPermit



Input: [0.247 0.753 0.6205] Plot points: 101
Opened system FUZZY AIR TRAFFIC CONTROL, 10 rules

(e) Clear

Fig. 7. Triangular membership functions

8. REFERENCES

[1] O. Godday, ‘Challenges facing the Aviation Industry in Nigeria’, 2010 http://247ureports.com/challenges-facing-the-aviation-industry-in-nigeria/

[2] R. Bach, C. Farrell and H. Erzberger ‘An Algorithm for Level-Aircraft Conflict Resolution’, pages 5–7, May, 2007.

[3] B. Capozzi, S. Augustine, T. R. Thompson, and J. E. Robinson, ‘An Initial Assessment of Benefits for Noise-Aware Decision-Support Tools’, pages 1–2, 2002.

[4] H. V. David, ‘Human Factors in Air Traffic Control’, Taylor and Francis Ltd. London, UK, 1995.

[5] G. D. Dennis, ‘TSAFE: Building a Trusted Computing Base for Air Traffic Control Software’, Master of Engineering in Computer Science and Engineering Thesis submitted to Massachusetts Institute of Technology, pages 19-43, 2003.

[6] L. Doitsidis, K. P. Valavanis, N. C. Tsourveloudis and M. Kontitsis, ‘A Framework for Fuzzy Logic Based UAV Navigation and Control’, Proceedings of the IEEE International Conference on Robotics and Automation, New Orleans, LA, April 2004, pages 1–6, 2004.

[7] M. Endsley, ‘Situational Awareness Information Requirements for En Route ATS’, 2007.

[8] Eurocontrol ‘Guidelines for Developing and Implementing Team Resource Management’, 1996.

[9] Federal Civil Aviation Authority (FCAA), ‘Manual of Air Traffic Control’, ATC1No 3,4&5, 1992.

[10] C. Gong, and D. McNally, ‘A Methodology for Automated Trajectory Prediction Analysis’, AIAA Guidance, Navigation, and Control Conference and Exhibit, Rhode Island, pages 2–7, 16 - 19 August 2004.

[11] R. J. Kelly and J. M. Davis, ‘Required navigation performance (RNP) for precision approach and landing with GNSS application’, Navigation, volume 41, number 1, pages 1-30, 1994, Wiley Online Library.

[12] Doc, ICAO, ‘Air Traffic Management’ 4444-RAC/501, http://www.paris.icao.int/ or www.icao.int, 2001

[13] D. McNally and C. Gong, ‘Concept and Laboratory Analysis of Trajectory-Based Automation for Separation Assurance’, Paper presented at AIAA Guidance, Navigation and Control Conference and Exhibit, 21-24 August 2006, 6600, Keystone, Colorado, pages 5-11.

[14] P. K.Menon, G. M. Diaz, S. S. Vaddi and S. R. Grabbe. ‘A rapid prototyping for en route air traffic management research software’, The American Institute of Aeronautics and Astronautics, Paper Presented at AIAA Guidance, Navigation, and Control Conference and Exhibit, San Francisco pp 1 18, 2005.

[15] E. R. Mueller and G. B. Chatterji ‘Analysis of Aircraft Arrival And Departure Delay Characteristics’, pages 19 113, October 2002.