Developing Air Traffic Control Simulator for Laboratory

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Abstract **– The widely-used ATC simulator laboratory in air traffic control education lacks research on its development. This study aims to develop a computer-based aerodrome control tower simulator for ATC using the research and development method. The simulator offers a realistic training environment, covering simulation, technicalities, facilities, configuration, equipment, specifications, software, operations, and development. It is a crucial facility in ATC courses at Indonesian aviation universities. Findings demonstrate its effectiveness in enhancing student proficiency and reducing reliance on external suppliers. The resulting design concept, developed through research and development, can be utilized by local experts to promote advanced technology mastery and cost efficiency in ATC training systems. It provides opportunities for local experts and serves as a model for other countries, advancing ATC education.**

Keywords **– Aerodrome control tower simulator, computer-based, ATC simulator training, advanced technology development, ATC simulator laboratory.**

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1. Introduction

Air traffic controllers (ATC) listed in ICAO Documents Rules of the Air and Air Traffic Services of the 1944 Chicago Convention have the task of preventing collisions between aircraft (separation in both lateral, vertical and longitudinal directions), preventing aircraft collisions with obstructions, managing the flow of air traffic that is safe, fast and orderly for aircraft, both those on the ground or those that are flying or passing using a predetermined route[1]. The interaction between air traffic controllers and pilots influences several human factors related to flight safety which include radio telephony communication and separation between aircraft [2].

Another task is to provide an overview of air traffic conditions to pilots obtained either through radar or non-radar including information on weather conditions and air navigation [3]. Based on the area of responsibility, there are three categories of air traffic controllers:

1. Aerodrome Control Tower (TWR): They are responsible for managing the arrival and departure of aircraft within the maneuvering area and airspace that is visible to the naked eye, typically within a range of 2 to 5 NM.
2. Approach and Terminal Control (APP/TMA): Their role involves guiding aircraft within the terminal control zone, which extends approximately 30 to 50 NM from the airport location. APP/TMA controllers are responsible for providing instructions for climb and descent.
3. Area Control Center (ACC): ACC controllers provide air traffic control services to aircraft operating within a specific geographic region, spanning several hundred miles from the airport location, particularly at the en-route or cruising altitude.

To carry out this task, an ATC officer is needed for managing air traffic flow starting from the plane making the first contact (communication) for departure until the plane lands (landing) at the destination airport.

In addition, it is necessary to support infrastructure, facilities, and regulatory instruments in accordance with the provisions issued by the International Civil Aviation Organization (ICAO), which from day to day continue to be amended in accordance with the development of air traffic flow and technology.

With the increasing frequency of flights crossing or landing at airports today, the duties and responsibilities of air traffic control operations services are becoming increasingly difficult. Therefore, the quality and reliability of the work equipment and human resources behind it must be really prime to ensure the avoidance of flight incidents. One of the ways in order to maintain the quality and reliability of ATC officers is by periodically holding license and rating exams for ATC officers. In order for the implementation of the ATC license and rating exams to be carried out safely and not to interfere with the operation of the ATC devices, a special vehicle is needed, namely what is called the ATC simulator. In addition to administering the license and rating exams, the ATC Simulator can also be used as a vehicle for recurrent or refreshing training for ATC officers and a means of introduction or familiarization for prospective ATC officers.

ATC simulator is a system consisting of hardware and software whose job is to simulate air traffic situations starting from ground control at the airport to the control area including simulating the condition of the aircraft and the environment in which the controlled aircraft is located [4], [5]. ATC simulator can be a bridge for students to learn about their skills in terms of air traffic control where simulations can be adapted to actual conditions at airports and simulated in ATC simulator [6]. In the ATC simulator, training participants can be trained on the following:

1. Practice detecting and preventing as early as possible the occurrence of collisions between aircraft, preventing collisions of aircraft with obstructions and airport vehicles in the airport area.
2. Practice dealing with abnormal conditions such as urgency and emergency situations
3. The exercise provides guidance for aircraft pilots both flying outside and inside the aerodrome area such as approach, take-off and landing.
4. Radiotelephony communication training with pilots in accordance with ATC rules as regulated by ICAO [7].

According to the level of use in the field, ATC Simulator is classified into 4 types, namely:

1. Aerodrome Control Simulator (ACS) is a replica of the actual ground and tower equipment and approach control which functions as a training vehicle for ground, tower and approach controller officers
2. APP/ACC radar (surveillance) simulator is a replica of the actual approach and area control center equipment which functions as a training vehicle for approach area and control area (APP/ACC) officers in providing radar (surveillance) services.
3. APP/ACC non-radar (Procedural Control) simulator Is a replica of the actual central approach and area control device that functions as a training vehicle for approach and central area control (APP/ACC) officers who provide non-radar services (procedural control) [8].
4. ADS-CPDLC Automatic Dependent Surveillance-Controller Pilot Data Line Communication is a replica of APP/ACC Radar (Surveillance) with ADS-CPDLC technology [9].

In general, the benefits of using the ATC simulator as a training tool are:

1. Reducing training operational costs, because ATC simulator operational costs are much cheaper compared to actual ATC devices.
2. Does not contain an element of risk in the event of a procedural error made by students during the training.
3. Training can be held at any time regardless of time, weather or natural conditions.

2. Theoretical Framework

ATC simulator is an air traffic control simulation package that can train students' experiments in guiding air traffic by making realistic simulations including aircraft criteria adapted to actual airport operational environmental conditions [10]. According to experts, simulation and games can be differentiated as follows:

Simulation: It is a realistic representation or model of the structure or dynamics of a real thing or process. Participants actively engage with the environment, interacting with people or objects, and apply their acquired knowledge to respond to problems or situations. They receive feedback on their actions, but there are no immediate real-life consequences.

Game: A game involves activities governed by specific rules, with varying levels of chance or risk. It typically includes one or more competing players, whether they are individuals, the computer, or oneself. The objective of a game is to achieve a specific goal by utilizing knowledge, skill, strength, or luck. In some cases, a game may incorporate elements of simulation, representing real-life situations or processes [11]. Simulation is an imitation of pretending. Simulation, derived from the term "simulate," refers to the act of feigning or behaving as if something is real, while simulation itself entails the imitation or pretense of a particular phenomenon or situation.

Some authors mention the benefits of simulation, including the following. Simulation can increase children's motivation and attention to topics, and children's learning, as well as increase students' direct involvement and active participation in learning. Improving students' abilities in cognitive learning [12], includes factual information, concepts, principles and decision-making skills. Student learning is more meaningful. There are several principles that teachers need to pay attention to when using simulations for learning.

a. The simulation is carried out by groups of students.
b. Each group gets the opportunity to carry out the same simulation or it can also be different.
c. All students must be directly involved according to their respective roles. Determination of topics adjusted to the ability level of the class, discussed by students and teachers.
d. In a simulation, three psychic domains should be achieved.
e. What should be attempted is the integration of several sciences. Simulation instructions should be made clear and easy for children to understand, especially for role holders.
f. Simulation is an exercise in motor and social skills that can provide learning experiences for students in dealing with real situations.
g. Simulation implementation needs to describe a complete situation, detailed process and sequence according to the real situation. Simulation is a computer program (software) that functions to imitate the behavior of certain real systems (reality).

The purpose of the simulation, among others, is for training (training), study of system behavior (behavior) and entertainment / games (games).

Some examples of computer simulations, among others: flight simulation [13] car simulation, banking system simulation, bank service queue simulation, war game simulation, macroeconomic system simulation, power plan simulation, urban planning simulation (Sim city), market game simulation, etc.

Real time simulation is part of informatics (information technology) which is currently developing very rapidly. Informatics studies that support computer simulation include: modeling and simulation, systems theory, software engineering and computer animation graphics. The stages involved in the development of a computer simulation are outlined as follows:

1. Gain a comprehensive understanding of the system to be simulated.
2. Create a mathematical model that accurately represents the system.
3. Develop a mathematical model specifically designed for the simulation.
4. Implement the simulation program by creating the necessary software.
5. Test, verify, and validate the output of the simulation to ensure its accuracy.
6. Execute the simulation program with a specific objective or purpose in mind.

3. Design Models

The design model for the development of aerodrome control simulator uses the Research and Development (R&D) method, where there are several important aspects in the development of aerodrome control simulator. The following are some of the aspects that an aerodrome control simulator must have, including:

3.1. Simulation Aspect

ATC Simulator must be able to create air traffic control scenarios such as operational conditions at airports [14], [15]. ATC simulators are commonly utilized in a range of applied and fundamental research projects. Typical ATC simulators strike a balance between replicating real-world field experience (realism) and offering experimental control [10]. Departure, arrival, overfly to an abnormal situation or emergency simulation [16], [17] must be simulated on the ATC Simulator so that it can provide knowledge to students about air traffic control skills and training [18].

Referring to the learning syntax of problem based learning, several learning activities for air traffic control can be described by providing problems that are adapted to the stages of learning.

The following is an exercise problem developed to train technique control in air traffic control learning. The simulation or air traffic control training problems in Table 1 can be used as an example by adjusting to actual operational conditions at the airport and used as a simulation in the ATC simulator.

Table 1. Simulation air traffic control training

No	Traffic	Status	Expected Performance
1	DEP	VFR	Taxi, Takeoff (Pistone Engine)
2	DEP	IFR	Startup, Taxi, Takeoff (Pistone Engine dan Turbo Engine)
3	ARR	VFR	Landing Instruction, Sequence Arrangement
4	DEP/ARR	IFR, VFR	Departure and Arrival Procedure, Traffic Information
5	DEP/ARR	IFR, VFR	Problem 4, Ground Vehicle, Helicopter Operation
	EXAMINATION 1		**All exercised items**
6	DEP/ARR	IFR, VFR	Problem 5, Local flight, Unexpected Traffic, Overflying
7	DEP/ARR	IFR, VFR	Problem 6, Communication Failure
8	DEP/ARR	IFR, VFR	Problem 7, Multirunway Operation
9	DEP/ARR	IFR	Departure and Arrival Instrument approach
	EXAMINATION 2		**All exercised items**
10	DEP/ARR	IFR	Problem 9, Missed Approach + Special VFR Operation
11	DEP/ARR	IFR, VFR	General Procedures
12	DEP/ARR	IFR, VFR	Change of Runway
13	DEP/ARR	IFR, VFR	Urgency Situation
14	DEP/ARR	IFR, VFR	Emergency Situation
	FINAL EXAMINATION		**All exercised items**

This simulation will enhance the students' air traffic control technical skills and provide valuable experience for their career advancement. In developing case studies, ATC instructors can use references from real-world experiences or simulation cases that are available in simulation software. The use of realistic and relevant case studies can also help improve student engagement in learning and allow them to gain in-depth experience in situations that are similar to real-world conditions.

The conclusion is that selecting the appropriate case study or scenario is crucial to the success of using realistic simulation in ATC education. Case studies should align with the learning objectives, cover complex air traffic situations, be adjustable to student abilities, and be relevant to real-world experiences or simulation cases available in simulation software.

With the appropriate selection of case studies, students can gain in-depth experience and improve their skills and confidence as future air traffic controllers.

3.2. Technical Aspect

ATC Simulator has a 360º field-of-view projected display generated by a circular LCD monitor (see figure 1) or Projector LCD (see figure 2) that forms a cylindrical space, provides a 360º graphical 3D terrain database, aircraft, airport buildings and lighting are modeled in 3 dimensions, both modeling and visualization provide accurate representation of the following parameters:

1. Airfield runways and taxiways: The layout and details of runways and taxiways are faithfully depicted in modeling and visualization.

2. Environment conditions and local weather effects: Both approaches accurately simulate and display the environmental conditions, including weather effects specific to the local area.
3. Time of day: Modeling and visualization accurately depict various times of the day, including daytime, dusk, and nighttime scenarios.

Model Flight is realistically modeled based on the flight performance of the aircraft. Pseudo pilot refers to a simulated or virtual pilot who operates an aircraft within a flight simulator or training environment (Figure 3). They are not actual pilots but individuals who assume the role of pilots during simulation exercises. Pseudo pilots have control over the simulated aircraft, follow flight procedures, communicate with air traffic controllers, and navigate through various scenarios. They play a crucial role in providing a realistic flight experience and training opportunities for practicing aviation skills in a controlled and safe environment. The features of pseudo pilots in ATC simulator are as follows:

1. Aircraft Control: Pseudo pilots can control the aircraft in the simulation using the provided control systems. They can use controls such as throttle, joystick, and pedals to accurately and responsively maneuver the aircraft.
2. Flight Settings: Pseudo pilots can adjust flight parameters such as speed, altitude, and aircraft heading according to the instructions given by air traffic controllers. They can make course changes, perform maneuvers, and follow designated flight routes.
3. Communication: Pseudo pilots can communicate with air traffic controllers and other pseudo controllers through an integrated communication system within the ATC simulator. They can use voice or text messages to coordinate, provide reports, or request instructions.
4. Aircraft System Modeling: ATC simulator incorporates advanced modeling of aircraft systems. This includes avionics systems, propulsion systems, engine controls, and other systems used in aircraft operations. Pseudo pilots can interact with these systems to understand and test the functionality of the aircraft.
5. Navigation and Flight Guidance: Pseudo pilots can utilize the provided navigation and flight guidance systems in the ATC simulator to assist them in aircraft navigation. They can access electronic maps, perform instrument-based navigation, and use autopilot systems to guide the aircraft to its destination.
6. Environmental and Weather Factors: Pseudo pilots will encounter various weather and environmental conditions within the ATC simulator. They may face situations such as adverse weather, traffic disruptions, or emergency conditions that affect flight decisions and required actions.

With these features, pseudo pilots can practice flight skills, understand air traffic control procedures, and face realistic situations in a safe and controlled environment.

Figure 1. Tower view ATC simulator

Figure 2. Tower view ATC simulator using projector LCD Source: (https://www.dlr.de/fl/en/desktopdefault.aspx/tabid-1964/1601_read-3011/)

Figure 3. Pseudo pilot view

4. Facilities Aspect

The ATC simulator is equipped with zooming facilities for objects and platforms as a substitute for binoculars, terminal area display from the ground, tower to approach area in 2D radar display presentations (see Figure 5), flight strip tray - functions as a storage area for flight strips, record replay - functions as a facility in evaluating student performance, digital audio as a medium of communication between positions (tower controller, approach controller, pseudo pilot, and instructor). Figure 4 is a computer instructor used to start the pre-set simulation, set the weather to be used in the simulation, add necessary situations in the simulation, the computer instructor has full authority in running the simulation process. The 2D radar display facility is essential in the ATC simulator as it has the function of detecting the position of aircraft in the air and assisting the controller in determining the sequence of landing, takeoff, and applying separation. The 2D radar display facility must display the identities of aircraft flying in the airspace in the simulation, including the aircraft's callsign, type, route, altitude, and heading (see Figure 5).

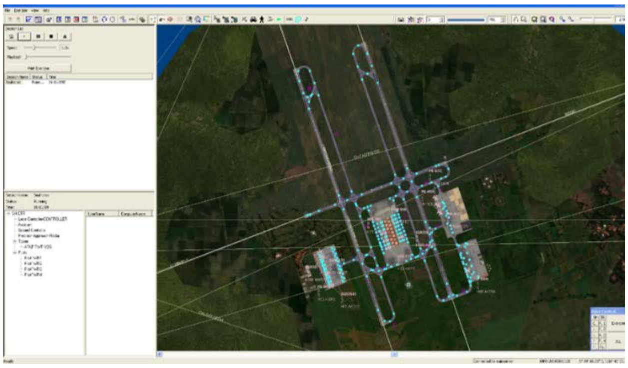

Figure 4. Instructor PC view

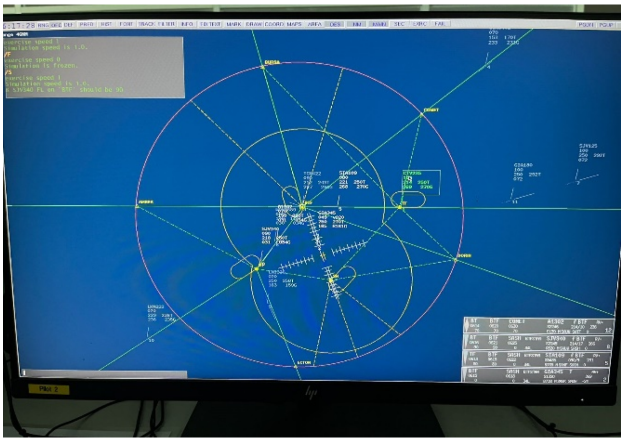

Figure 5. 2D Radar Display

5. Configuration Aspect

The aerodrome control simulator configuration is built using a network system (LAN) that is connected to each other through a Router Hub as shown in Figure 3 which consists of two tower controller units each acting as executive and assistance controller positions, one approach controller position unit , three units of pseudo pilot position, one unit of instructor position (see figure 6).

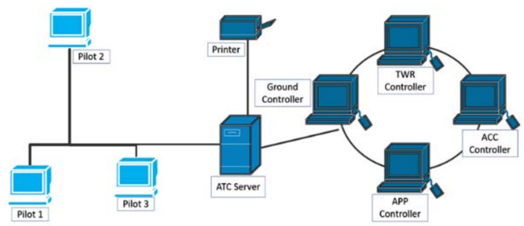

Figure 6. LAN network configuration on the router hub

6. Equipment Aspect

Each position is designed in the form of a console or rack cabinet containing hardware, including a workstation in the form of a PC computer complete with keyboard and mouse, console display in the form of a 24inch LCD monitor used as a monitor controller, audio communication System consisting of:

1. Audio Headset: a device worn on the head that provides audio output and input for communication purposes,
2. Loudspeaker: a device that produces sound at a higher volume and is used for broadcasting audio in a broader area,
3. Telephone set: an apparatus used for audio communication through telephone networks,
4. Soft audio communication control panel: a software-based control panel that manages and regulates audio communication as an audio control selection facility in the form of a 21.5" LCD Touch screen monitor used as a Voice Communication Control System (VCCS) (see figure 7),

Flight strip is a sheet or card used in air traffic control to record and manage important information about flights. Each aircraft operating in the airspace is given a flight strip that contains the aircraft's identity, type, flight route, altitude, speed, and special instructions. Flight strips are typically color-coded, with blue or green for departure aircraft, yellow for arrival aircraft, and white for local flights or overflights.

Flight strips are used by air traffic controllers to monitor and manage aircraft movements. They are arranged in a specific order based on flight priorities, such as arrival or departure sequence. Flight strips can also be used to provide instructions to pilots, such as route changes or altitude adjustments.

In modern air traffic control systems, flight strips can exist in physical form (paper) or in electronic form displayed on computer screens (see figure 8 and figure 9). Electronic flight strips allow controllers to easily access and manage flight information, as well as monitor real-time aircraft movements.

Flight strips are an essential tool in maintaining safety and operational efficiency in the air traffic control environment. By using flight strips, controllers can easily track and manage air traffic, as well as provide accurate instructions to pilots to ensure flight safety.

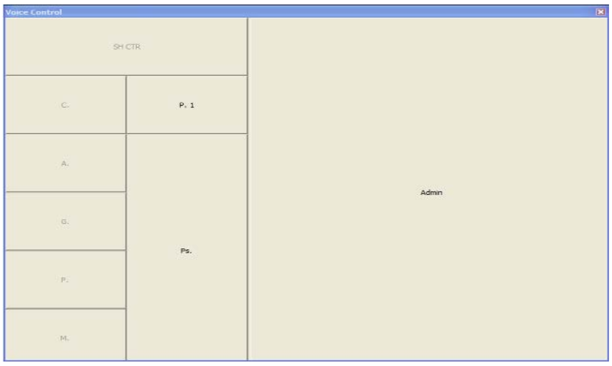

Figure 7. Voice communication control system

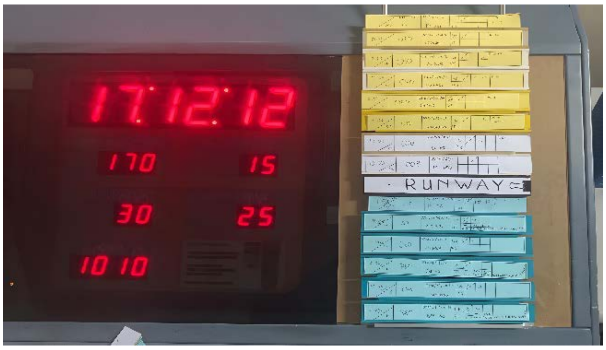

Figure 8. Manual flight strip

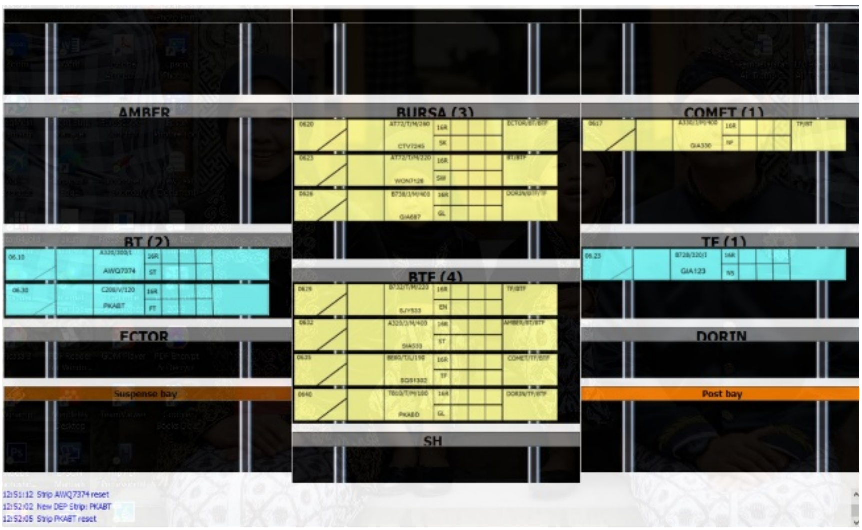

Figure 9. Electronic flight strip

7. Aspects of Specifications

The technical specifications for the aerodrome control simulator system are classified into 3 components including hardware, software, and operations.

a. Hardware

The Aerodrome Control Simulator hardware component consists of 3 systems namely:

1) Computer System: used by system manager has the following technical specifications:
   a) Industrial Server
   b) Tower Case
   c) Server Rack
   d) RAM 8GB DDR3
   e) Gigabit Ethernet NIC
   f) DVD-ROM
   g) Monitor LCD 24", 1920x1080
   h) VGA Card 8GB
   i) Mouse & Keyboard

2) The computer used for the tower controller has the following technical specifications:
    a) Industrial PC Core i5/i7: A high-performance computer designed for industrial use, equipped with an Intel Core i5/i7 processor.
    b) Dual head graphics adapter 4GB: An adapter that supports dual monitors and has a dedicated graphics memory of 4GB.
    c) Hard disk drive 1TB SATA: A storage device with a capacity of 1TB using SATA technology.
    d) LCD monitor 24inch 1920 x 1080: A 24-inch LCD monitor with a resolution of 1920 x 1080 pixels
    e) LCD monitor 21.5inch 1920 x 1080: A 21.5-inch LCD monitor with a resolution of 1920 x 1080 pixels
    f) RAM 8GB DDR3
    g) Mouse & keyboard
3) The touch screen computer used for the pseudo pilot position has the following technical specifications:
    a) Industrial PC Core i5/i7
    b) 1TB SATA Hard Disk Drive
    c) Dual Head Graphics Adapter VGA 4GB
    d) Random Access Memory (RAM) with a capacity of 4GB using DDR3 technology.
    e) A 24-inch LCD monitor with a resolution of 1920 x 1080 pixels
    f) A 21.5-inch touch screen LCD monitor with a resolution of 1920 x 1080 pixels
4) Audio communication system
    a) A 22-inch LCD monitor with a resolution of 1920 x 1080 pixels
    b) Telephone set
    c) Sound blaster card
    d) Loud speaker
    e) Audio headset
5) Visual display system for aerodrome control view
    a) A large-sized LCD monitor with options of 60-inch, 65-inch, or 75-inch, featuring a resolution of 1920 x 1080 pixels.
    b) A visual image generator that includes an industrial PC equipped with an Intel Core i7-2600 processor, 4GB DDR3 RAM, a 1TB SATA hard disk drive, and a 2GB VGA for graphics processing.

b. Software aspect

Aerodrome control simulator software has the following technical specifications:

1. Database.

The database is a collection of data needed to execute the simulator which includes:

1) Flight plan: A detailed document that outlines the intended route, altitude, and other flight-related information for a specific aircraft journey.
2) Flight procedure: Standardized instructions and protocols that guide pilots during various phases of flight, such as takeoff, landing, and navigation.
3) Airspace: The designated portion of the atmosphere that is controlled and regulated for safe aircraft operations, including different classifications such as controlled, restricted, and uncontrolled airspace.
4) Navigation aids (NavAids): Electronic devices or systems, such as radio beacons, GPS, or visual markers, used by pilots to navigate and determine their position during flight.
5) Air route: A designated path in the sky that aircraft follow to travel between specific locations, typically defined by navigational aids and air traffic control.
6) Airport condition: The state or status of an airport, including its infrastructure, facilities, and operational readiness for aircraft operations.
7) Exercise and scenario: Simulated or practice situations that are created for training purposes, allowing individuals or groups to practice specific skills or respond to certain scenarios in a controlled environment.

2. Modeling

Modeling software involved in the simulator execution process includes:

1) Flight processing – software that models the characteristics, performance and operations of airplanes from the point of view of the ATC controller starting from the take-off process to landing in normal, abnormal or emergency conditions including adverse environmental influences.
2) Radar processing: The software that simulates and encompasses all components associated with radar processing, including radar detection, radar view display, and radar tools.
3) Graphical User Interface (GUI): A software program based on the Windows operating system that features a menu system and displays a radar view, as depicted in Figure 5. The menu system is specifically created, based on the user's role, such as tower controller, approach controller, pseudo pilot, or instructor.

3. System management software

System management software is activated via the computer instructor position, used by system administrators for tasks or jobs related to aspects of system maintenance such as:

1) Configuration system with database update: The system responsible for managing and updating configurations, including the database.
2) User account management (user types, passwords, access rights): The process of managing user accounts, including different user types, password management, and assigning access rights.
3) Online/offline data reporting: Reporting data in real-time when the system is connected online or storing data locally when the system is offline and reporting it later.
4) Simulation load/unload: The action of loading or unloading simulations, typically referring to the process of starting or stopping a simulation.
5) Backup and restoration: The process of creating copies of data or system configurations for protection and recovering the system to its previous state in case of data loss or system failure.

4. Voice simulation

Voice simulation at each position is provided by an audio station, which is a facility to interact/communicate verbally between positions (controller, instructor and pseudo pilot positions) within the scope of the Approach system and Tower Control Simulator. This voice simulation software was developed using VoIP (Voice Internet protocol) technology. Audio Communication This system provides two-way communication facilities according to the functions and needs as follows:

1) Administration communication: This communication feature is responsible for coordinating the entire system and is exclusive to the instructor position. It allows communication from the instructor position to the controller positions (Tower and Approach), from the instructor position to the pseudo pilot position, or as a broadcast to all positions. The admin button on the communication system in the instructor position is used to initiate this communication, and the desired type of communication can be selected.
2) Ground to ground communication: system that facilitates coordination between the tower controller and approach controller positions. It enables functions such as handovers and flight plan requests. To activate this feature, the designated controller position button on the communication system in each controller position needs to be selected.
3) Ground to air or air to ground communication serves as a radio frequency simulation that is used to interact between the controller position as the approach controller or the tower controller with the pseudo pilot position as the aircraft operator. The radio frequency has been set according to the assigned frequency in each airspace or sector. This facility is activated by selecting a button in the controller position or in the pseudo pilot position. Visual simulation visual simulation software was developed to generate the appearance of 3D objects, platforms and their environment on the screen. This software is equipped with a database of aircraft and airports in 3D as well as objects that are on the ground.
4) Record replay is a facility for instructors to record activities carried out by students during training, both activities carried out by hand (mouse and keyboard) and verbal activities. The recording of these activities is stored in the form of data and audio files on the hard drive, which are called recorded files. Meanwhile, replay or playback is a facility for playing back recorded files so that all student activities during the training can be seen again. This options are used by instructors to analyze and evaluate student performance in the form of comments or suggestions when students make mistakes. this replay activation can be done in the instructor position.

8. Operational Aspect

In general, the operational aspects of the aerodrome control simulator are explained below:

a. Training preparation

The instructor is responsible for the preparation of the training process. This includes the preparation of various data before the training takes place, which comprises courseware or exercises, flight plans, aero map data, and navigation aids (NAVAIDS)

b. Implementation of Training

1) Configuration of Training

The training session is the main factor that determines the success or failure of a training mission in the approach and tower control simulator. The training session defines an execution environment which includes the defined airspace and system parameters relevant to the exercise to be executed.

When a student logs in, the position student will identify the predetermined training session to run. Training sessions are activated, controlled, and stopped by the instructor.

2) Exercise Supervision

Exercise supervision is carried out by an exercise supervisor such as:

a) Exercise initiation selection of an exercise to be carried out involving the installation and validation of the exercise.
b) Exercise resumption initializes the execution process of an exercise that has been installed.
c) Exercise suspension freeze or temporarily stop the execution process of an exercise
d) Exercise termination terminating the process of executing an exercise that is no longer needed.
e) Record as material for evaluating student performance after training is complete (post evaluation training).
f) Post training evaluation After the training is completed, the instructor can evaluate the performance of his students by using the replay or playback facility.

3) Design Approach

The approach taken in the design and development process of the aerodrome control simulator is as follows:

a) Reference Documents that are used as a reference in the implementation of the Simulator design are:
   (1) ICAO – Standard and Recommended Practices (SARP) Document
   (2) Directorate General of Civil Aviation (DGCA)- Civil Aviation Safety Regulation (CASR) Document
   (3) User Requirements document ICAO and DGCA documents contain regulations governing the existence of an aerodrome control simulator regarding all requirements and terms of qualification and validation. While the user requirement document contains all the requirements and needs of the user both software, courseware and hardware so that the ATC radar Simulator that the user receives really matches what the user wants.
b) Engineering design standard – is used in the development of the aerodrome tower simulator adjusted to the type of product, namely:
   (1) DoD STD 2168 - document published by the US Department of Defense containing standard guidelines in the software development process. The goal is to provide convenience for the user, especially in terms of operation and maintenance of the software.
   (2) ISO – a document published by the International Organization for Standardization which contains standard guidelines in hardware development and manufacturing processes. As is the case with DoD 2168, the ISO document also aims to provide convenience for users in operating and maintaining hardware products.
c) Commercial of The Shelf (CoTS) products All components needed in the construction of the aerodrome control simulator are made to the maximum extent possible in the form of CoTS products. With the intention that it is cheap in the purchase price and also cheap in operational and maintenance costs.
d) State of the art technology is a concept that applies the latest technology regarding software and hardware.
e) Human factor engineering with the implementation of the human factor engineering concept, it is expected that the resulting product will attract users to own it and be comfortable in using it and easy to operate. The concept is implemented in the form of:
   (1) Software development is carried out on the basis of a "Graphical User Interface Program", namely software based on Windows programming by paying attention to the interaction between the system and the user. In addition, the application software developed must also have the characteristics of "User Friendly"; so that it will provide a guide that makes it easy for the user.
   (2) The design of the console and Windows display is done in such a way in terms of shape, layout and color composition so that it will provide convenience and comfort in using it.
f) Object-Oriented Programming (OOP) is a programming paradigm that focuses on organizing a program into separate objects, allowing for modular and non-linear development.

Examples of object-oriented programming languages include Microsoft Visual Studio's Visual Basic and Visual C/C++. The advantage of using OOP is that it enables easier debugging and error correction, as each object module can be independently created and traced.

g) Programming languange is a programming language and compiler used in the development of ATC tower simulator depend on the specific requirements and applications, which may include:
   (1) The operating systems options include Windows and Linux.
   (2) For creating the graphical user interface, Microsoft Visual Basic is utilized.
   (3) Interface programming is carried out using Microsoft Visual C/C++ and Microsoft Visual C#.
   (4) Dynamic modeling software is implemented using Microsoft Visual C/C++.
   (5) SQL Server is employed as the database program.

9. Development Aspect

The aerodrome control simulator development team consists of several people who are experts in their fields with the following duties and responsibilities:

a. Courseware developer: Responsible for the design and manufacture of courseware.
b. Software engineer: responsible for designing and developing:
   1) The user interface of the program.
   2) Aircraft modeling and simulation.
   3) Simulation of the audio communication system.
   4) Programs for real-time execution and client-server interaction.
   5) Visual database in the form of aero map coverage.
   6) Software utilities.
c. Quality and assurance engineer: responsible for controlling and validating product quality based on international standards including the creation of documentation.
d. Mechanical & electrical system engineer: Responsible for designing the manufacture of consoles regarding the mechanical and electrical aspects.
e. Support engineer: Responsible for supporting projects in the following areas:
   1) Procurement, logistics and finance
   2) Administration, accommodation and transportation
   3) Program planning and control
f. Project engineer: Responsible for controlling and monitoring day to day activities and coordinating the team in project implementation.
g. Program manager: Responsible for making project planning and evaluation of project implementation.

10. Discussion

The use of Air Traffic Control (ATC) simulator is crucial in training and improving the skills of air traffic controllers in managing aircraft traffic in the air and around the airport. The ATC simulator has various specifications that make it a very effective training tool in preparing users to face situations that may occur in the real world.

One of the main specifications of the ATC simulator is its realistic 3D graphics. This allows users to see accurate visualizations of the conditions around the airport and in the air, including moving aircraft, airport buildings, taxiways, and the surrounding environment in 3D graphics. Realistic graphics help users to better understand the surrounding conditions and improve their effectiveness in managing aircraft traffic.

In addition, the ATC simulator has accurate physics models, which allow aircraft in the simulation to move as in the real world. This includes the ability to change the direction and speed of the aircraft, as well as the ability to maneuver in emergency situations. Accurate physics models help users train their skills in facing different situations and improve their ability to manage aircraft traffic more effectively.

The ATC simulator also provides various weather conditions and situations [19], including bad weather, emergency situations, and other unique situations. This helps users prepare and train their skills in facing different situations. With the ATC simulator, users can train their abilities to face situations that may occur in the real world, thereby increasing effectiveness and efficiency in managing aircraft traffic.

Radio communication features are also an important specification of the ATC simulator. This feature allows users to communicate with aircraft pilots in the simulation, so that users can manage aircraft traffic more effectively and efficiently. Effective radio communication is crucial to flight safety and improving the ability of air traffic controllers to manage aircraft traffic.

In addition, the ATC simulator allows users to create and save custom scenarios to be trained, such as emergency scenarios or other unique situations. This allows users to customize their training to their specific needs and improve their skills in facing situations that may occur in the real world.

Integration with real radar systems is also an important specification in the ATC simulator. This allows users to train their skills in interpreting radar data and managing aircraft traffic more effectively. Integration with real radar systems can also help users to better understand and predict aircraft behavior and surrounding situations, thereby increasing effectiveness in managing aircraft traffic.
Another feature commonly found in the ATC simulator is the ability to record and playback completed exercises. This allows users to review and re-evaluate their exercises, as well as identify any mistakes and difficulties that may occur. By reviewing their exercises, users can improve their skills and effectiveness in managing aircraft traffic.

11. Conclusion

The Air Traffic Control (ATC) simulator has specifications that are crucial in improving the skills of air traffic controllers in managing aircraft traffic in the air and around airports. Realistic 3D graphics, accurate physics models, various weather conditions and situations, effective radio communication features, the ability to create custom scenarios, integration with real radar systems, and the ability to record and playback training exercises are some of the main specifications of an ATC simulator. By using the ATC simulator, users can train their skills in dealing with situations that may occur in the real world and improve their effectiveness and efficiency in managing aircraft traffic.

The implementation of the ATC simulator concept design is an opportunity as well as an arena for simulator professional experts in each local country to prove their ability to develop ATC simulator training systems or tools. Providing opportunities and trust to local experts is very important for the development of mastery of advanced technology. At the same time serves as a model for reducing dependence on developed countries or supplier vendors, so as to save on maintenance costs, updating, and upgrading systems or repairs if there is a system failure.

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