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FOSS BASED AIR TRAFFIC CONTROL SIMULATOR

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Abstract

This paper presents an analysis of the significance of Air Traffic Control (ATC) simulators in training, and focuses on the development of low cost, high awareness ATC simulator on a 3D virtual environment, using Free and Open Source Aircraft simulator named Flightgear. Here it has proposed a scenario based ATC officer control method covering the all three phases; tower control, approach and enroute control.

Keywords: Aircraft Traffic Simulators; Virtual Environment; Flightgear; Training.

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1. Introduction

Air Traffic Controlling (ATC) is a very crucial part in the aviation field around the world. It primarily deals with providing flight related information to aircrafts through radio communications, in order to guide them with take-off, landing and enroute flight, minimizing the risk of collision [1]. This is done by a special crew, who work in ground base station, mostly inside towers adjacent to runaways in the airport. This crew, the ATC actors or ATC controllers, needs to be highly skilled in situation awareness and quick decision making, since correct guidance is necessary for safety and success of air traffic controlling [2]. According to the researches a significant number of operational errors are caused by the ATC actors due to faulty coordinators or failure Team Corporation [3]. Based on the study carried out by Federal Aviation Administration (FAA) in 2002 it is revealed that 90% errors are attributed to some category of communication errors [3]. FAA has proposed some criteria on how to implement a human factors training program and how to evaluate the training [4]. Since all the ATC actors should have a proper knowledge in commanding to aircrafts through precise verbal communication, after inspecting the instruments that track the path and status of planes such as radar screens. Therefore such crewmen should be highly trained on collaborative communication and action before they are given to handle a real situation.

Hands on training of new crewmen in a real ATC tower may be of a risk just as the training of new pilot officer; therefore we may have to opt for much suitable method using a simulated virtual environment, where the trainee ATC controller is immersed in just as new air plane pilots are trained in flight simulators. Such simulators are named Virtual ATC Simulators.

Such solutions are available as commercial computer simulation systems produced by different vendors. Since these simulators deal with the training of people in highly mission critical environments, they require having good quality in performance and virtualization aspects.

As these ATC simulators available in the market are sophisticated commercial solutions with high initial cost, this study was focused on discovering any capability of producing a closer to reality ATC simulator with Free and Open Source Software (FOSS) currently available for flight modeling and simulating which will ultimately facilitate the users to customize the solution for their purposes and requirements.

2. ATC Simulators

The ATC simulators can be categorized according to the type of the air traffic they simulate as well as their implementation methods. In generally the whole scenario for a trainee can be divided into three cases; towel control, approach control and enroute control. All these must be covered within a simulation environment to get perfect hands on experience for a trainee. Hence this ATC simulator will be a teamwork oriented simulation where the communication and perfect sync with each actor is required.

2.1.Tower Control

Tower control consists of the activities and procedures to control movement of any vehicle (ground objects and flying objects) within the airport boundary. This boundary normally defined as an airspace volume with a radius of 2-30 miles and a height of 1,500 to 2,000 feet centered in the airport. The control tower is the highest place within the airport and usually has windows that cover 360 degrees of viewable area. The tasks performed by ATC control can be categorized again based on their characteristics as illustrated in Figure 1.

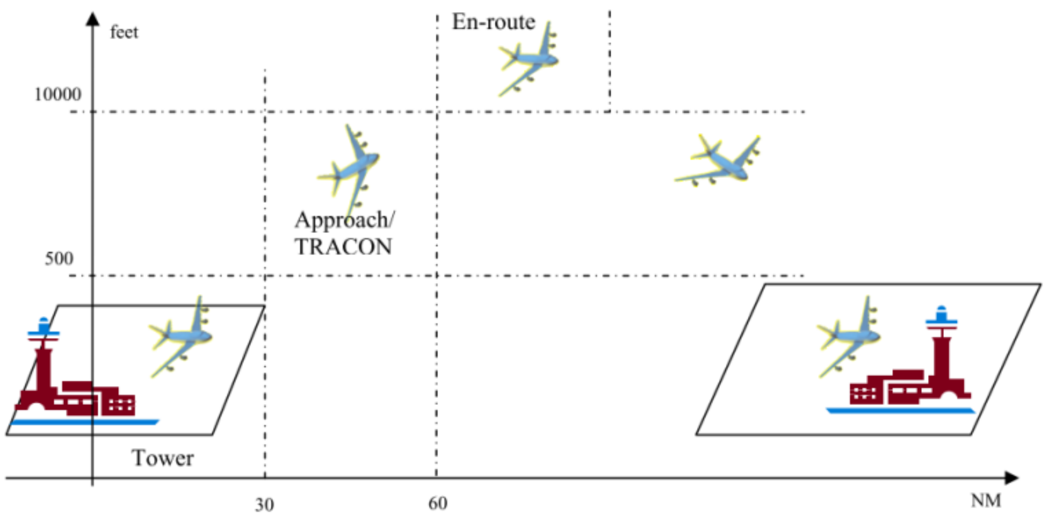

Figure 1: Different cases of ATC scenario [5].

- Flight data control
- Clearance control
- Ground Control
- Local control

2.2.Approach/Departure Control

In generally the approach control in an ATC is used interchangeably with Terminal Radar Approach Control (TRACON). A TRACON controls aircraft within an airspace defined by a radius of 30-50 nautical miles from the centre of the airport and 10,000 feet from the surface to above. There are four types of air traffic controls by TRACON.

- Arrival
- Departure
- Overflights
- Aircrafts operating under Visual Flight Rules (VFR), or Flight Instrument Rules (FIR).

Arrival aircrafts are controlled by the TRACON with collaborative with other flying objects tracked in the air space ensuring the aircraft landing and maintaining a clear runaway. The controller has to ensure the runaway clear before the next aircraft touch the land/runaway as well as to request space expanding to allow aircraft to depart or cross the runaways.

Departure aircrafts are handed over to the approach control when the flying height is between 1,000 feet to 2,000 feet. At this point the TRACON officer has to control and clear traffic until the aircraft is placed on a predefined track and in a geographical location.

Over-flight aircrafts enters from one point and exit from another point without landing. Those objects should be controlled in a manner that they do not interfere with the climbing or descending traffic. This enroute over flight aircrafts should be controlled and altered to ensure this traffic is possible.

Visual Flight Rules are a set of rules and regulations under which a pilot may operate an aircraft, with his own when the weather conditions are sufficient to allow the pilot to visually control and maintain separation with obstacle and other aircrafts. Transponders are mandatory for the VFR aircrafts as they need to transmit altitude level, SSR code and amplify the radar signal. VFR pilot can request "VFR advisory service" from the ATC controllers. In that case officers have to advise the VFR pilots on the traffic and the weather information. In this case it requires detailed communication as the VFR pilots actions are depending on the commands given by the ATC officers. If the officers are exposed to such situations in advanced and have experiences in managing such situations in to some extent, then it will be really advantageous in quick decision making.

IFR pilot should submit their flying route to the ATC officers and accept any revisions ATC request to their route. ATC controllers are required to separate flying IFR from the terrain as well as from all the other flying IFR aircrafts with a minimum separation. Once the IFR aircrafts are above 18,000 feet then the aircrafts are considered in the "Positive Control Airspace" where only IFR aircrafts are allowed. Then the ATC controllers have to control IFR pilots with these limitations and ensure the safety of airspace.

2.3.Enroute Control

Enroutes control starts when the aircraft exceed the TRACON volume and reached its Cruising speed and altitude. The enroute control officers are responsible for climbing the aircraft to their requested altitude while ensuring all the aircrafts are safely separated from each other. Cross traffic, severe weather, special missions that require large airspace allocations and traffic density are some cases which complicates maintaining the flow consistency of an aircraft. Within enroute there can be more than one control point as the Area Control Centers (ACC) is responsible for defined thousands of square miles of aerospace. There handing-off process is performed to maintain a seamless control for aircraft which should be simulated in an ATC environment.

3. Development of ATC Simulator

Flightgear is a FOSS, multi-platform flight simulator [6]. It provides a versatile solution towards an educational flight simulator with a wide support community, and this has been proven by previous research and developments [7]. It has capabilities of simulating the Airport environment with related buildings, runway, taxiways and terrain details.

Flightgear provides a framework to model the internals of the cockpit. A much wider viewing can be achieved using a multi-screen method dividing the cockpit view, into three sub-views displayed in separate screens and then combined to seamlessly tiled display.

It also comes with support for multiplying with a local multiplayer server. This server allows several instances of Flightgear running on different pilot station computers, to be integrated and communicated with each other's. This creates a virtual environment of an airport with simulated aircrafts, operated by users in pilot stations. The setting is usually used as a gaming environment. Another special instance of Flightgear on a separate station acts as an instructor station and it only brings a general behavior of the aircraft models without a cockpit view. Furthermore a freeware radar simulator, Open-radar [8] can be connected to this setting, which gives a radar view simulating the radar screen used by ATC controller in the tower. A typical setting of Flightgear for multiplayer flight simulation use is shown in Figure 2.

Major changes were incorporated to this setting, to transform the setup into an ATC Simulator. The instructor station module that displays the overall scene of the simulated environment will be converted to the Aerodrome View. The Aerodrome Module displays the Airport view from the ATC tower control.

Since we need to simulate many number of aircrafts with different aerodynamic profiles, assigning each aircraft to a pilot station running on a single computer, would be more tedious. Therefore we need to inject simulated aircraft's into multiplayer server. Usually the pilot stations communicate with the server using a custom protocol named the Flightgear Multiplayer Protocol [9]. Each pilot station application sends its status information using this protocol as messages to the server. The information includes mainly the Call Sign of the aircraft, the model of the aircraft and its position in the Earth Centered Coordinate System.

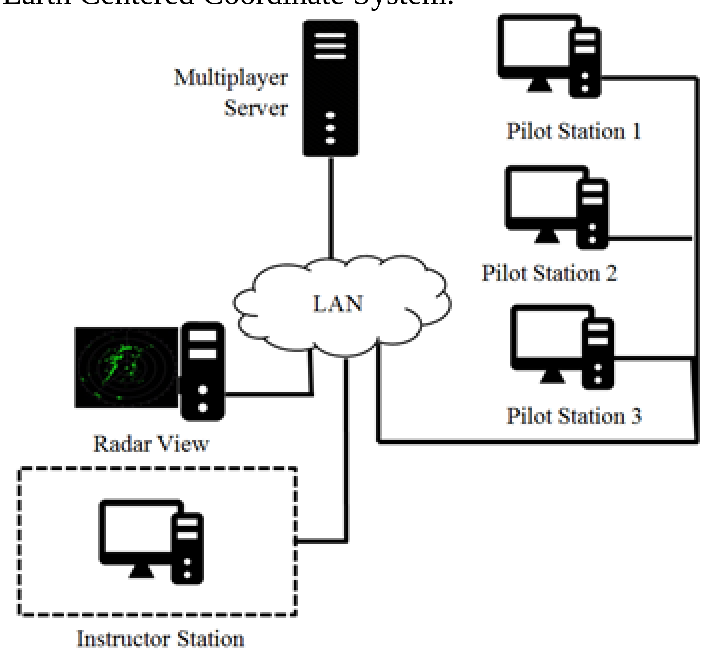

Figure 2: Typical setting of a Flightgear gaming environment.

In our approach we developed a separate module that simulates these messages with using predefined flight Call Signs and Models and position information. This module can inject many numbers of such predefined messages with different Call Signs and Models and related position information, creating a simulated situation for the server as if it receives them from many real pilot stations. This scenario will be simulated in the Aerodrome View as well as the Radar View. The Aerodrome view would display these simulated aircrafts travelling in their paths in the virtual Airport environment, while the radar view simulating a radar screen.

The primary control of the simulation is by the ATC training instructor. For this purpose an Instructor Station module is introduced, it comprises of techniques to organize and control the simulation session plus a duplicate view of the Aerodrome simulate again through a Flightgear instance connected to the multiplayer server. The instructor initiates the training session by giving a flight plan to simulator module as the input. This flight plan comprises the call sign of hypothetical aircrafts, its type of aircraft to simulate and its path starting from the hanger along the taxiway, to the runway and it en-route path in air. Even after when the flight plan is loaded the instructor can command the simulator module to change the path of a particular aircraft through a command console.

The path of each simulated aircraft is arranged as a set of waypoints in the real world coordinates, with their heading and orientation details for each waypoint. Once it is input to the simulation module, the path is interpolated by a path interpolation method implemented with a bezier curve interpolation method [10]. When the path is needed to be modified the command is sent as a direction or the next waypoint to the simulation module by the instructor module and the next path is interpolated instantly.

The bezier curve interpolation of path is a very simple form of creating a path between points. The Bezier curve is a parametric curve **P(t**) that is a polynomial function of the parameter with **t** with degree ***n*** as follows,

$$P(t) = \sum_{i=0}^{n} P_i \, B_i \qquad 0 \le t \le 1$$

where, B_i is the weighting function depend of n given by

$$B_{n,i}(t) = {}^{n}c_i \, . \, t^i (1 - t)^{n-i}$$

The degree of the polynomial, denoted here by ***n***, depends on the number of points used to define the curve. These points are called control points and each point influences the direction of the curve by pulling it toward itself, and that influence is strongest when the curve gets nearest the point. Therefore it passes only through the first and the last points and not through intermediate control points. The number of points are decided by the application, and here in this case we used a cubic Bezier curve with 4 control points, n = 3. Such path is shown in Figure 3.

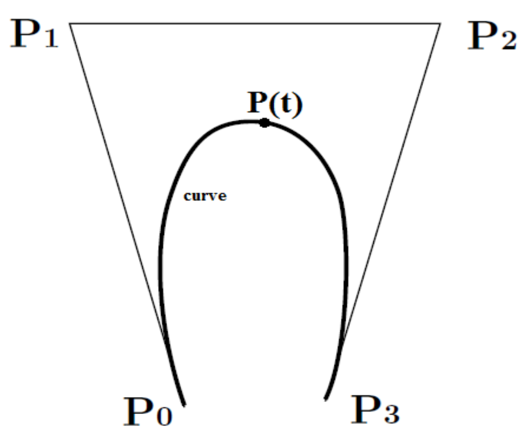

Figure 3: Typical cubic Bezier curve.

We selected $\mathbf{P_1}$ as the first waypoint and $\mathbf{P_4}$ as the second waypoint, and point $\mathbf{P_2}$ and $\mathbf{P_3}$ was selected so that vectors $\mathbf{(P_2 - P_1)}$ is in direction of aircraft at waypoint $\mathbf{P_1}$ and $\mathbf{(P_4 - P_3)}$ is in direction of aircraft at waypoint $\mathbf{P_4}$. **P (t)** is the position of the simulated Aircraft over the curve. The final design of the system is shown in Figure 4.

4. Conclusion and Future Works

Due to the lack of training or the hands on expertise safety issues are arises in every field, around the world. In aviation field the risk engage in training as well as in the live action is actually higher comparing to any other domain. A simple mistake can compromise one's life or cause a great damage to the resource in use. Hence the training and situational awareness is a must in aviation domain.

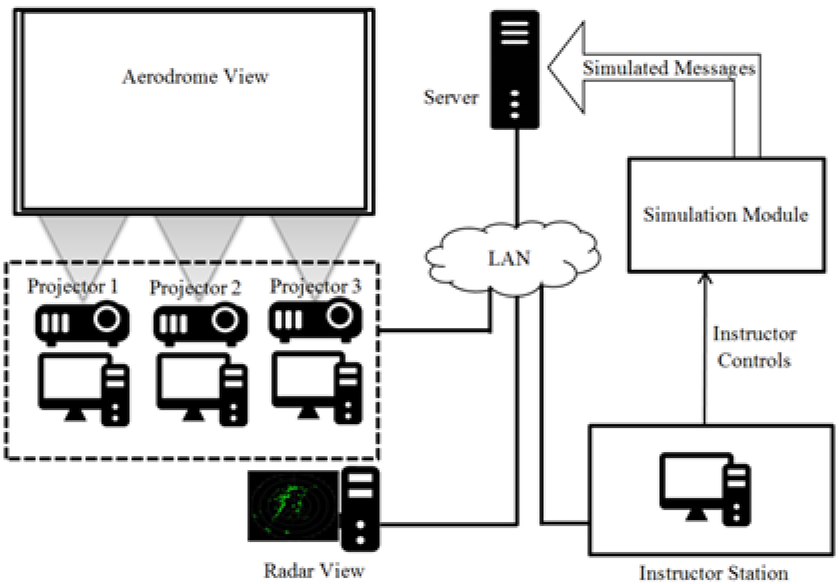

Figure 4: ATC simulator system with Flightgear.

With the FOSS Flightgear application we have designed and developed an ATC simulator platform to train ATC actors. Here we have introduced a scenario based training process for each actor. Exercise scenarios are gathered by analyzing the live flying data for the designed airport (GPS, Yaw, Pitch, speed, etc.). These exercises cover the basic communication and commands skills in tower control, enroute and departure controls units. Terminal based aircraft control system is integrated in order to control the aircraft route according to the verbal commands received by the control units. External actors are required apart from the tower control, enroute and departure controls unit actors to operate aircraft objects using this terminal control. Otherwise single users can be assigned to operate predefined aircraft type which will be assigned to the IP address of the PC running as a single instance of Flightgear.

With the proposed modifications this low cost ATC simulator platform can serve in training all the ATC actors enhancing their communication, situational awareness and also quick decision making skills.

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