DEGREE'S FINAL PROJECT

THESIS TITLE: Symbolic Representation of Scenarios in Bologna Airport on Virtual Reality Concept

DEGREE: Air Navigation Degree and Airport's Degree

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DIRECTOR: Francesca De Crescenzio

DATE: January 2017

"Is easier to travel in a plane, even to pilot it; than to understand how it can fly"

John von Neumann

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Resumen

Este proyecto forma parte de un gran proyecto denominado Retina Project, el cual se centra en reducir la carga de trabajo del ATC. Haciendo uso de los últimos avances tecnológicos, como es la realidad virtual.

El trabajo ha consistido en estudiar diferentes situaciones adversas que se dan acabo diariamente en el aeropuerto de Bolonia. Se ha analizado un escenario con buena visibilidad donde predomina el sol y otros dos escenarios con mala visibilidad, donde predomina la lluvia y la niebla.

Una vez hecho el estudio y los cálculos necesarios para obtener la visibilidad de un controlador en estos tres escenarios, se ha llegado a la conclusión de que el overlay tiene que ser mostrado con una dimensión constante independiente de la posición del avión y tanto el frame como el flight strip debe de ser de un color llamativo (rojo) para un mejor control por parte del ATC.

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Abstract

This paper is a part of a big Project named Retina Project, which is focused in reduce the workload of an ATCO. It uses the last technological advances as Virtual Reality concept.

The work has consisted in studying the different awareness situations that happens daily in Bologna Airport. It has been analysed one scenario with good visibility where the sun predominates and two other scenarios with poor visibility where the rain and the fog dominate.

Due to the study of visibility in the three scenarios computed, the conclusion obtained is that the overlay must be shown with a constant dimension regardless the position of the aircraft to be readable by the ATC and also, the frame and the flight strip should be coloured in a showy colour (like red) for a better control by the ATCO.

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ACRONYMS

A-LPV – Localizer Performance with Vertical Guidance

ACAS – Airborne Collision Avoidance System

ACC – Area Control Center

ADD – Acceptable deferred deflect

AMAN – Arrival Management

ANSP – Air Navigation Service Providers

AOCC – Air Operations Control Center

AOP – Airport Operation Plan

APM – Approach Path Monitor

APOC – Airport Operation Centre

APW – Area Proximity Warning

AR – Augmented Reality

ASM – Airspace Management

ATCo – Air Traffic Controller

ATFCM – Air Traffic Flow and Capacity Management

ATFM – Air Traffic Flow Management

ATIS – Automatic Terminal Information Service

ATM – Air Traffic Management

ATS -- Air Traffic Services

ATSU – Air Traffic Service Units

C-HUD – Conformal–head-up Display

CCD – Continuous Climb Departure

CDA – Continuous Descend Approach

CDM – Collaborative Decision Making

CDO – Continuous Descend Operation

CNS – Communication Navigation Surveillance

CTA – Control Area

CTA – Control Time of Arrival

CTA-APP – Approximation Controller

CTA-DEL – Clearance Delivery Controller

CTA-GND – Ground Controller

CTA-TWR – Tower Controller

CTOT – Calculate Take of Time

CWP – Controller Working Position

DCB – Demand Capacity Balancing

DMAN – Departure Management

DME – Distance Measuring Equipment

DPI – Departure Planning Information

EID – Ecological Interface Design

ETMA – Extended Terminal Manoeuvring Area

FPL – Flight Plan

FUM – Flight Updates Messages

GBAS -- Ground Based Augmented System

HMD – Head Mounted Display

HMI – Human Machine Interface

HUD – Head-Up-Display

IAF – Initial Approach Fix

ICAO – International Civil Aviation Organization

IOP – Impute Output Processor

LIPE – ICAO Bologna Aerodrome

LTM – Local Traffic Management

MDL – Multipurpose Data Link

MDPP – User Driven Prioritization Process

MSAW – Minimum Safe Altitude Warning

MSP – Multisector Planner

MTCD – Medium Term Conflict Detection

NDB – Non-Directional Bacon

NOP – Network Operation Plan

PBN – Performance Based Navigation

PSR – Primary Surveillance Radar

RA – Resolution Advisory

RETINA – Resilient Synthetic Vision for Advanced Control Tower Air Navigation Service Provision

RNAV – Area Navigation

RNP – Required Navigation Performance

RTOT – Monthly Mean Total Precipitation

RX24 – Daily Extreme Precipitation

SA – Situational Awareness

SBAS -- Satellite Based Augmented System

SESAR – Single European Sky ATM Research

SMR – Surface Movement Radar

ST-HMD – See-Through Head-Minted Displays

STAM – Short Term ATFCM measures

STAR – Standard Terminal Arrival Route

STCA – Short Term Conflict Area

SWIM – System Wide Information Management

TA – Traffic advisories

TCAS – Traffic Alert and Collision Avoidance System

TCT – Tactical Controller Tool

TMA – Terminal Manoeuvring Area

TMA – Terminal Manoeuvring Area

TOD – Top of Descent

TTA -- Target Time Arrival

TTO – Target Time Over

TTOT – Target Take of Time

TWR – Tower

UTC – Coordinated Universal Time

V/AR – Virtual/Augmented Reality

VOR – VHF Omnidirectional Range

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INTRODUCTION

The Project consists in the study of several climatological adverse situations that are continuously happening in Bologna Airport. In this way it is useful for the Retina Project to achieve the main objective of developing a virtual reality glasses for the ATC to help on their workload. The next report outline describes in an accurate way the content developed in each chapter.

Report Outline

This Project research is based in the following chapters:

1. **SESAR program operations**: The study of the conflict management and the tools used; how the weather is taken into account and the use of SWIM system.
   Finally the study of how is done the integrated and collaborative network management.

2. **Retina Project**: Explication of the general concept of the project focusing on the Airport of Bologna and the overlays that the ATC must deal with.

3. **ATC overlays issue**: Research of the actual ATC and the work developed by each type of them. Research of the most important awareness situations that the controllers may deal with.

4. **Modelling Overlays:** In this chapter the factors and actuators of the scenario have been numerated and created. Different climatological situations have been simulated and a final scenario including all the factors, actuators, weather, etc. has been represented and simulated.

5. **Conclusions:** Summary of the job done and the results obtained.

CHAPTER 1. SESAR PROGRAMME

1.1. Background/ History

SESAR (Single European Sky ATM Research) is the technological pillar of the Single European Sky. Its main objective is to improve Air Traffic Management (ATM) performance focusing on definition, development, validation and deployment of innovative technological and operational ATM solutions. These innovative solutions constitute what is known as the SESAR concept of operations.

1.2. Sesar Programme operations

1.2.1. Conflict Management and support tools

New technologies brings significant changes as the improvement of improve accuracy of ground-based trajectory that allow better performance of Controller support tools in order to reduced Controller task load per flight.
Conflict management supports tools to allow Controller to handle traffic as they are able to predict conflicts with sufficient accuracy and look-ahead time.
The main objective of ICAO is to reduce to an acceptable level the risk of collision between aircraft and hazards. Conflict management is applied at three levels:

- ✓ Strategic conflict management
- ✓ Separation provision
- ✓ Collision avoidance

Strategic conflict management

Strategic conflict management is intended to reduce the need to apply separation provision to an appropriate level, thereby reducing Controller workload. There must be a balance between the previous objective and the need to preserve the optimal business/mission trajectory.
This topic is achieved through the integrated operation of airspace organisation and management, demand and capacity balancing and queue management based on more accurate 4D trajectory data provided by the Airspace Users.

The user has a preferred trajectory that takes into account the ATM constraints like the strategic conflict management or the synchronization of traffic to improve the planning.

Separation provision

Acording to SESAR management and ICAO separation concepts there are new elements. Separation minima have not been declared yet, then it is assumed that such minima have to progress for each separation mode. Due to this, there is a great linkage between area of conflict management and support tools with Safety Nets. Although the independence of Safety Nets still remains a core requirement.
Separation provision often uses advanced tools to solve conflicts, with MTCD and TCT.

Air Safety Nets

Air Safety Nets is to be based on air and ground and its purpose is to provide time alerts during the airbone phases.
A prerequisite for a safety net is able to work independently on the other functions of the system, on the ground or in the air; this way it can reach a single data error cannot invalidate safety layers.
In SESAR, the dual safety layer afforded by independent airborne and ground based safety nets has a very important role in maintaining the required level of safety.
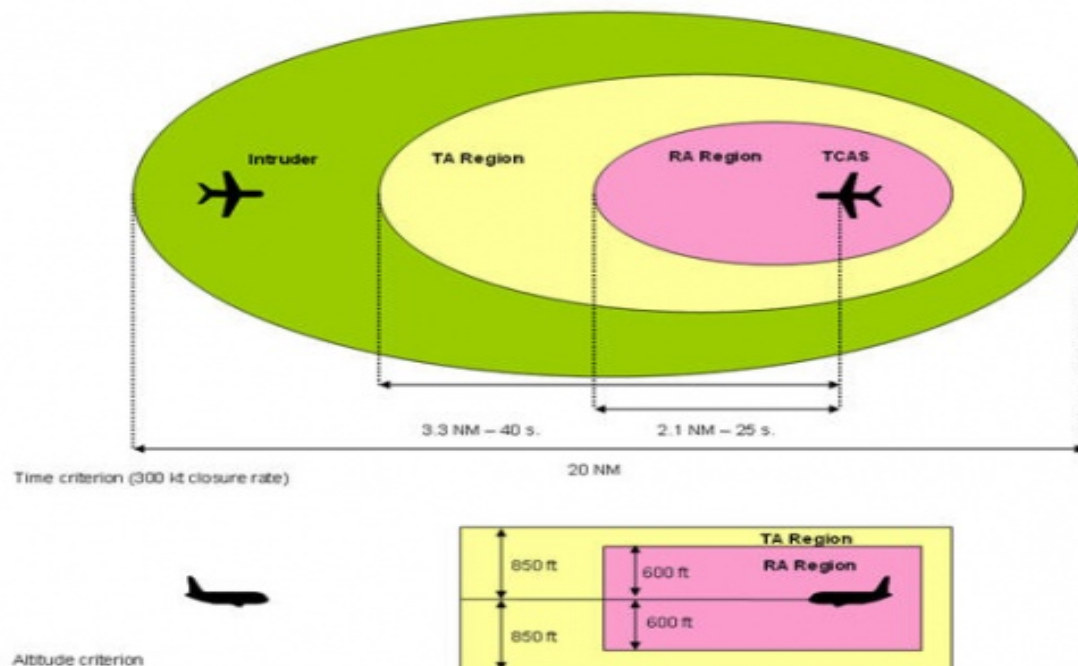
Figure 1. Advanced tool to solve conflicts

Multi-sector Planning

When controllers are informed of a flight through the radar or electronic strips, he processes it. All information that is not automatic has to be processed by controller. Because of this the workload of the controller increases.

In recent years, controllers have had to change their working methods adapting to the new system capabilities, to increase the capacity. Free routing is less predictable than a conventional network.

The initial integration process is more demanding for Controllers, reverting to the longer notice time allocated to each CWP to process a flight would not be an option as it would demand a greater amount of resources and therefore would reduce the capacity of the sector.

Controllers in step one of free routing can rely more with tools and methods. A Multi Sector Planner has the ability to integrate a flight in its area of responsibility and thus take early decisions to conflict. An extended view of the airspace throws MSP allow to see better the problems. This makes that MSP takes early conflict management decisions and optimise complexity resolution measures.

Limitations

It is necessary electronic coordination capabilities to automate controller's work to reduce the system workload:

- ✓ Should allow that controllers can carry out the coordination of adjacent sectors.

- ✓ Provides support to transfer flights between controllers and ATSU, for that reason facilitates needs an early resolution of conflicts through inter ATSU/sector coordination.

The context of dialogue/coordination between En-route and ETMA/TMA ATSU/sectors has to be contemplated with the complexity of traffic.

Human aspect

The support tools have the function of assisting the flight crew and controllers on the airspace uncontrolled or on the limit of controlled airspace. All next airspace will not be class A (restricted access), so it needs to improve safety in all categories of airspace.

Strategy to reduce Controller task load

To solve the controller workload without increase ANSP costs, three following points are included:

- ✓ Automate daily workload through better methods of data input and data management improvements.
- ✓ Automation support to conflict/interaction detection and situation monitoring and conflict resolution.
- ✓ Reduction of conflicts via a range of de-confliction methods.

1.2.2. Efficient Terminal Airspace Operations

The particular challenge for terminal area operations is to reach a high level of airport capacity while having a reasonable level of over-flying traffic. This is achieved while maintaining standards of noise reduction and more efficient aircraft flights.

Enhanced Route Structures

A very important aspect in airspace capacity is the controller's workload. Thanks to SESAR, improves the complexity management and increases capacity by reducing the requirement for tactical intervention.

To manage congested flows, it is deploying routes that provide a greater degree of strategic de-confliction and procedures that capitalise on the greater accuracy of aircraft navigation. Then the workload is reduced and the accuracy of the aircraft navigation improves the controller's knowledge.

An example to follow is Point Merge Systems use RNP capabilities to improve traffic sequencing with the reduced Controller workload.
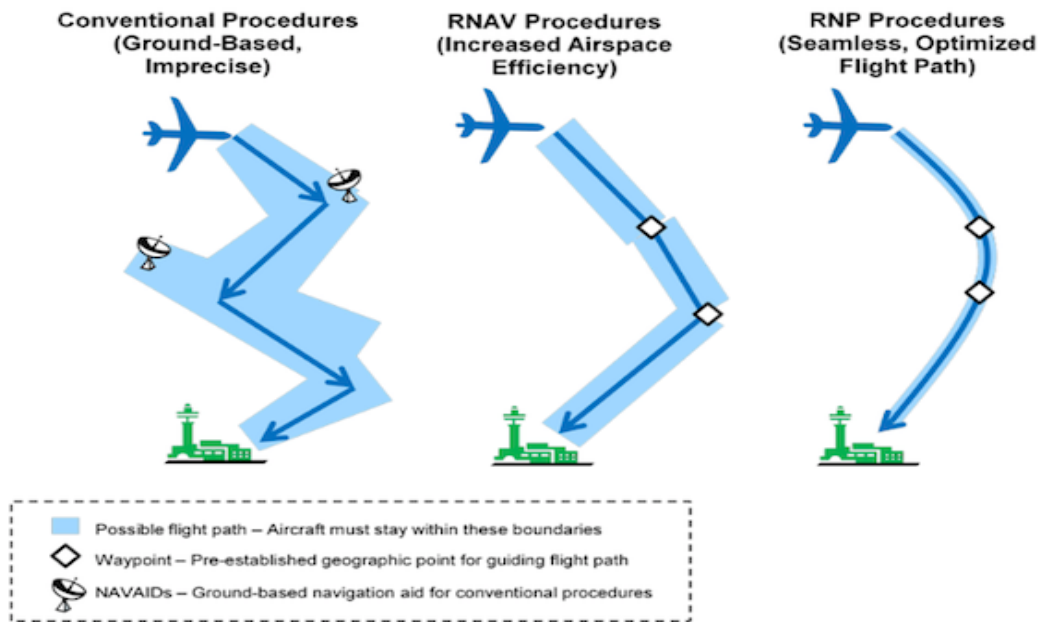
Figure 2. Conventional, RNAV, and RNP Navigational Methods

It must be considered that TMA task-load can be managed through the Controlled Time of Arrival (CTA) for Traffic Synchronization which helps to manage the complexity by controlling the traffic flow into the fixed route structures.

TMAs still depend on fixed routes, but are optimized through Performance Based Navigation (PBN) using Advanced RNP.

With the implementation of advanced RNP both En-route and Terminal airspace give benefits such as:

- ✓ Generate routes with 2D structure, with the vertical dimensions of the flight managed by the controller to be able to optimize as much as possible the vertical profile.

- ✓ The RNP routes have the function of optimizing flight efficiency improvements, such as fuel combustion, as they are not limited by ground-based navigation aids.

- ✓ Another advantage is that RNP-capable aircrafts have a relative positioning more predictable. Therefore, the positioning for the flight trip is improved as for the ATCO.

o *Human aspects:*

The fact of the Enhanced Route does not change the responsibilities of the controllers or crew.

This new implementation simplifies procedures and increases the predictability of the position. On the other hand due to the introduction of new procedures, the controller will start using closed-loop control (e.g. Clearance to a pre-defined waypoint/route) and open-loop control will become less frequent used (e.g. continue on heading).

Improved Vertical Profiles

It is necessary to take into account the vertical profile of climbing and descending traffic to improve flight efficiency, such as fuel combustion or environmental factors such as noise.

The CDA is usually applied from Initial Approach Fix (IAF) to runway threshold. SESAR, in alignment with CDO, proposes that the continuous descent must be executed as low as possible, ideally at the top of the descent.

This implementation in vertical profiles on descent improves the awareness of the situation as it provides security benefits.

The operational procedures are designed such that, when traffic density permits, CDA and CCD can be accommodated on a tactical basis. Dependending on the traffic density/complexity level-offs may be required to provide separation between flows (arrivals versus arrivals or arrivals versus departures).

With the application of continuous climb and continuous descent (CCD or CDA), intermediate altitude clearances are no longer applied. This reduces the cockpit workload and the risk of misinterpretation of clearance.
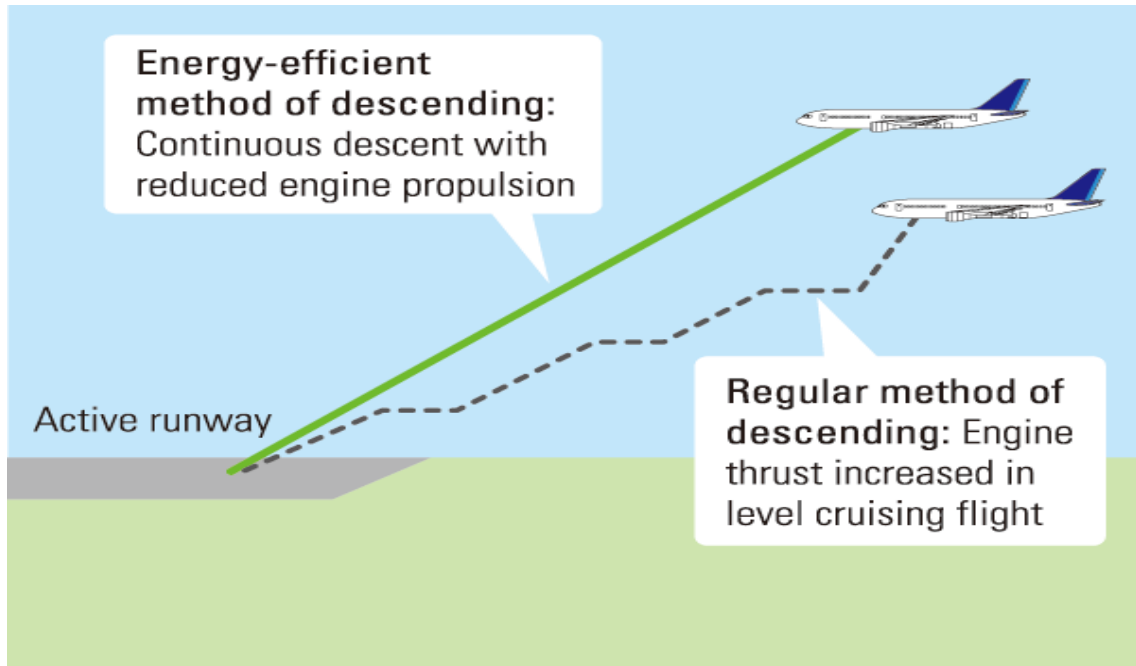
Figure 3. Continuous Descending Approach

o **Tailored arrival**

Tailored arrival procedures are defined as flights from Top of Descent (TOD) to Initial Approach Fix (IAF) or to runway taking in account other traffic and constraints. In this way the descent is optimized and minimise the need for low-level airborne holding. ANSP information is taken from the actual data of the aircraft (such as weight, speed, etc). The uplink of the assigned route (STAR) as calculated by the ANSP.

o **Limitations**

The aircraft and ground systems are equipped to facilitate down-linked ADD (wind and temperature are specifically important) and up-linked route data. Sharing these data makes the profiles more efficient and the tactical provision of the CDA is more likely and efficient, but does not preclude the implementation of CDAs and CCDs.

o **Human Aspects**

The fact of the Improved Vertical Profiles does not change the responsibilities of the controllers or crew but the methods of operation change. One key example of is the management of the Top of Descent in En route airspace, which is now an event well defined by the process of the Continuous Descent Operations, is that the controller cannot manage this Top of Descent to

achieve a CDA while it is only considering the aspects of conflict management.

1.2.3. Weather resilience

Bad weather can cause delay in flights, restrictions on trips or a very drastic measure such as closing an airport. This phenomenon can have a negative impact on the ground handling of an aircraft. SESAR wants to be able to develop new systems to cope with these disruptive events and in the case that they fulfill these adversities to be able to operate as if they were in normal weather conditions. When an airport has low visibility conditions, the flow of aircraft is affected and reduced.

Flight Crew Enhanced Vision

In conditions of low visibility, head up and head down, landing and ground operations allow lowering approach limits, improving taxi time efficiency and increasing safety margins. Enhanced vision of the external environment is also combined with Advanced Localizer Precision with Vertical guidance approach based on SBAS (A-LPV/SBAS).

Low Visibility Procedures using GBAS

In the previous point when giving solutions to work better in low visibility conditions is done collaboratively between airports with the same meteorological problems. Then low Visibility Procedures and Precision Approaches using initial CAT II/III GBAS are more systematically used.
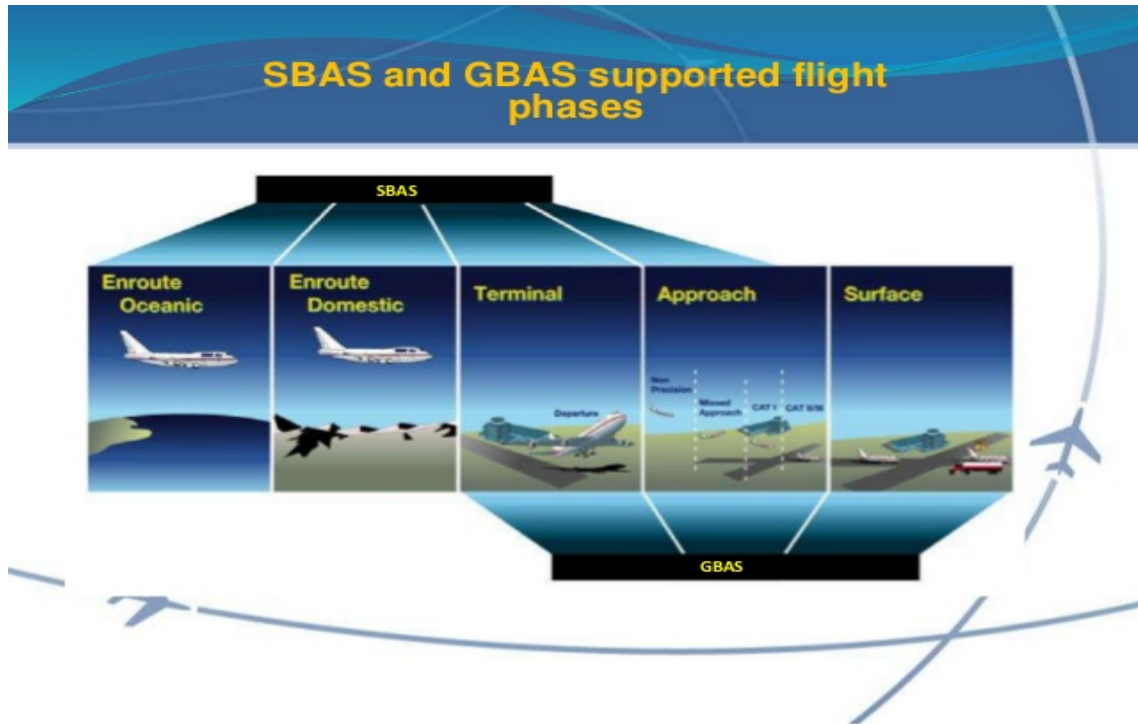
Figure 4. Flight Phases

1.2.4. Swim

The SWIM (System Wide Information Management) manages the information along its full life cycle and across the whole European Ground ATM system.

This concept enables direct ATM business benefits to be generated by ensuring the provision of commonly understood quality information to the right people at the right time delivered at the right place. SWIM tries to improve the management of the ATM information, improving the decision-making in real time and situational awareness across all ATM stakeholders sharing the same information.

SWIM favours the fact that all partners can have access to up-to-date data. It enables extensive iteration process based on the exchange of accurate flight information and refined estimates between ANSPs.
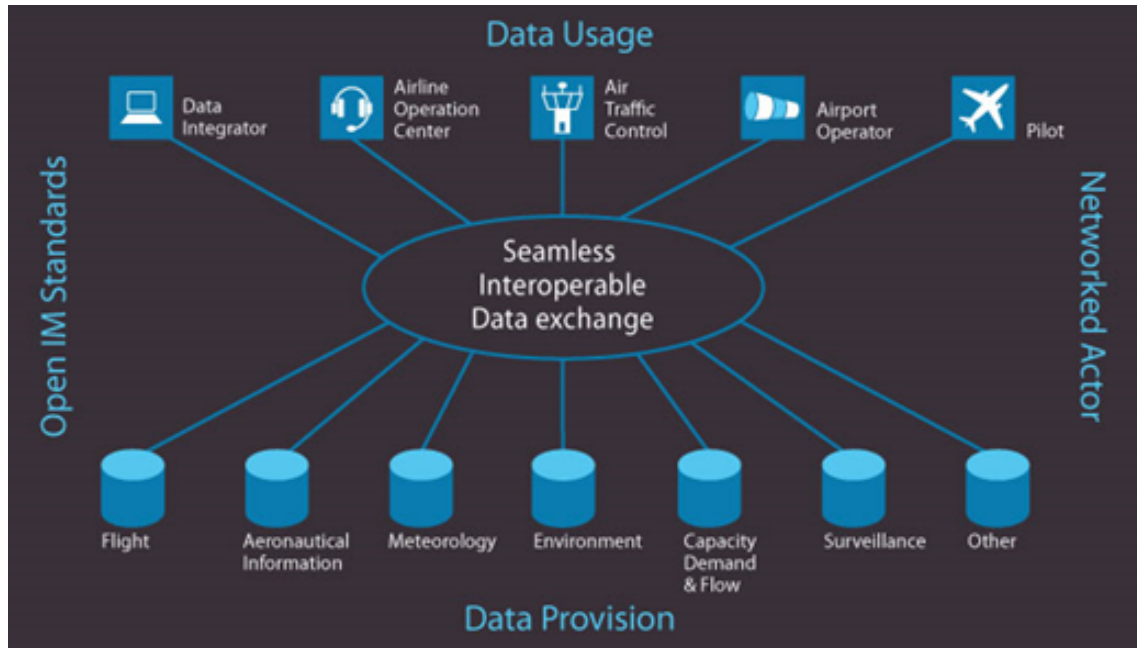
Figure 5. System Wide Information Management

1.2.5. Integrate and collaborative network management

Demand and Capacity Balancing Airport & En-Route

The most significant changes found by the Integration and the collaborative network management on the demand and the capacity balancing airport and en-route is the following:

1. Enriched Flight Planning
2. Management of TTA/TTO for smoothing constraints
3. Dynamic Sectorization and improved Civil/Military coordination
4. Enhanced ATFCM
5. Airport CDM integrated in the Network Operations

Focusing on different Operational Areas, each one contributes in a manner to performance as the predictability, Airport and airspace capacity, Environment and fuel efficiency, safety, flexibility and cost effectiveness.

o **Network Operations Planning**

ATFCM/ASM Planning and Demand Capacity balancing are iterative processes, which generate and detail the Network Operation Plan (NOP) and the Airport operation plan (AOP). Developed in a Collaborative Decision

Making (CDM) approach involving local, sub-regional and regional actors and Airspace users, processes are updated accordingly as sharing precise and update the data on the day of operation approaches.

UDPP is used at first to manage localy the Airport capacity reduction, dealing first with the take-off congestion.

MDL process is based on the exchange of information using existing technologies matching with SWIM. So at first, UDPP deal with the exchange between users of the airspace of the take-off flights in a CDM airport.

A-CDM concept for regulated and non-regulated and also the procedure ATFM Swapping Swap for regulated flights are used.

o **Enriched Flight Planning**

The enrichment of FPL data by operational flight plans including flight performance parameters is possible by the improved operability between the network management Systems and the airspace users.

Network Management Systems receives the user-preferred trajectory, computed by the AOCC, which corresponds to the operational FPL taking into account ATFCM/ASM constraints.

o **Management of Target Time Over/Arrival (TTO/TTA)**

The objective is to given on answer to the business need of the user while improving the effectiveness and the smoothing effect of regulations on the demand in congested airports and areas by enabling the adherence to the target time (TTO/TTA).

CTOT enables the aircraft to meet the TTO/TTA target at the destination airport, taking into account other possible constraints. At the time the CTOT is specified the Target Take Off Time (TTOT) is assigned to the flight by the DMAN within the CTOT tolerance range.

Airport Operators can access the TTA information before the flight arrival to the AMAN Horizon and uses it to plan airport operations, as stand management, taxi routing, pre-departure sequence and DMAN management.

Flight Crew might be informed by the AOCC of the TTA at destination when this limitation is the most penalizing of the flight. This information helps to manage either adjust the flight in the most economic way.

o **Civil Military co-ordination:**

✓ Flexible Military Airspace: objective gives more freedom to select the route trajectory, achieve more flexibility for both (civil and military partners) and responds better to military airspace requirements either meteorological constraints.

- ✓ <u>Before Day of operations:</u> Local, national and Sub-regional actors with Network Manager evaluate the impact of mission trajectories on airspace demand and find solutions to optimise network either regional and local capacity.

- ✓ <u>Day of Operations:</u> As the deviations from the Network operations plan are coordinated, permits quick decisions, taking advantage of opportunities of the benefits of the airspace in a dynamic manner minimizing the impact of disruptions.

o **Dynamic sectorization:**

Improving predictability of Sector Capacities as ANSP define and share sector capacities in an active manner.
The system works on the allocation of airspace and route structure, though dynamic management in order to optimise controller workforce.
Finally the flexibility in the management of the sector is important to ensure a balance between traffic or airspace demand and capacity at the European network level.

o **Enhanced ATFCM Processes:**

1. <u>Sector supervision and configuration management systems</u> are sufficiently flexible to support different sector configurations as required by ANSP, ensuring consistency with the Network situation through ATFCM process.

2. <u>Interactive Network Capacity Planning</u> offers an interactive support to stakeholders in the development of medium-term plans. Is used to relieve bottlenecks by applying consolidated capacity planning process. The most important factors are the coordination and network synchronisation of ANSP/airports to adapt the capacity delivery where and when is required.

3. <u>Enhanced ATFCM/ASM/ATS coordinated process</u> optimises the available capacity based on the continuous assessment of network impact of the expected airspace allocations via collaborative activities within the planning and execution phases between ASM and ATFCM.

4. <u>Dynamic DCB / Short-Term ATFCM Measures</u> constitute a step forward to close the gap between ATFCM and ATC.

   It anticipates and manages traffic peaks and complexity to moderate ATC workload through the application of fine-tuned measures.

   In order to do so, improved procedures that require dynamic coordination between Local Traffic Managers, Airspace Users and the Network level (through CDM) are developed to monitor and calculate the workload.

STAM consist of specified measures applied to a limited number of flights after coordination with direct effect on workload resolution and delay reduction.

This process focuses on minute-based activity complementing current global hour-based capacity management.
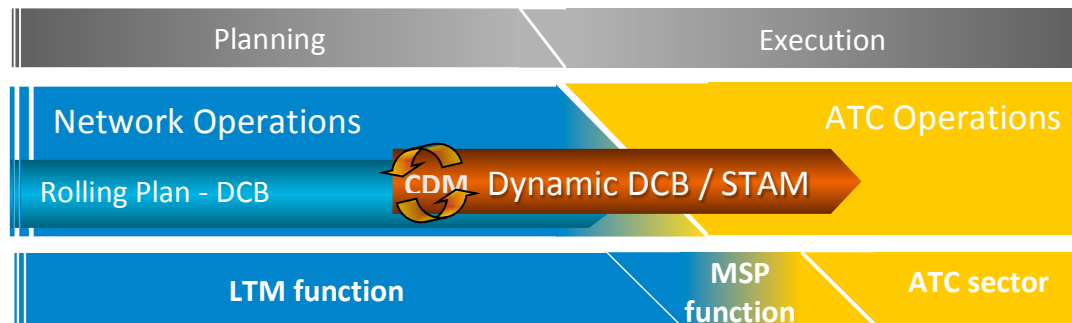

Figure 6. DCB evolution in SESAR

- o **Airport Operations Planning and Airport Collaborative Decision Making (A-CDM)**

The improvement of the Demand and Capacity balancing procedures is based on the integration of Airport Operations into the Network Operations.

The aim of this process is to reduce delays, improve the predictability of events and optimise the utilisation of resources of Airport CDM Partners.

The APOC (Airport Operations Centre) is the main actor in this coordination role from the airport perspective by providing monitoring; diagnosis and decision support capabilities and either implement mutually agreed action, updating the Airport Operations Plan (AOP) and also checking the progress of the plan.

Due to the exchange of information between AOP and NOP, it ensures the best overall system outcome, and at the same time, takes into account the needs of the airport, the individual airspace users as well as those of the Network as a whole.

A-CDM airports at regional level and the Network Manager Exchange information through AOP/NOP affecting all IFR flights either regulated or not, sends updates to flight milestones times through FUM and DPI.

- o **Human Aspects**

    - ✓ Working environment: the aim is to improve the traffic prediction tool set of these changes.

✓ <u>Procedures, roles and responsibilities:</u> increase of coordination takes place between the Network Manager and the Local traffic Manager, TWR/ACC Supervisor and APOC. Instead of increasing the workload, it improves traffic and workload predictions, leading to a better predictability of capacity and allows the supervisor have a better overview of the traffic.

- Improving the occupancy forecasts and associated workload assessments it is expected to lead to an increase level of safety and operational productivity. This allows a better management of resources at the Network and ATSU level.

✓ <u>Training and development:</u> Controllers and supervisors will need to be trained in the procedure and the HMI.

Complexity Management

The main objective of the complexity management is simplifying the ATM situation so that the Separation Provision can be efficiently provided by human intervention. It begins with the detection of zones of high complexity to ensure the safety and orderly management of air traffic following these processes:

✓ Safe transition from free route operations to route based operations
✓ An optimum sector organization to provide the most efficient service, using Dynamic sector configurations and multi sector planning
✓ Modification of individual trajectories to reduce complexity
✓ Implementation of measures on traffic flows in order to react to specific ATC constraints.

The most significant changes found in complexity management are the automated tools that allow a continuous monitoring of traffic demand and evaluation of complexity. Also the complexity assessment activities are consistent between Network Management functions and ATC with none disruption.

o **Complexity characteristics**

Complexity describes the difficulty for an Air Traffic Controller to handle the traffic under his responsibility. The main contributing factors are the traffic demand, airspace characteristics, aircraft performance diversity and meteorological events.

o **Complexity and Workload Assessment**

Complexity assessment relevant for network management is an activity based upon likely interactions of traffic flows, traffic pattern and airspace demand on traffic load and Controller workload. Also it is sensitive to specific geographical parameters.

o **Automated tools:** They are needed to manage complexity.

o **Complexity Management – Operation in complex environments**

When traffic complexity is evaluated and managed as a precursor to the Separation Management Process, the complexity management begins. ATFCM and ASM take timely actions to adjust capacity, airspace configuration or demand profiles through various means, in collaboration with ATC and Airspace Users.

Complexity management supports other things:

✓ Strategies to solve the imbalances between demand and capacity.
✓ Appropriate airspace configuration: transition from free route to route based operations.
✓ Optimum sector organization.
✓ Modification of trajectories by route, level or timing.

Dedicated monitoring tools are shared with ATC to ensure, a full consistency between complexity assessment activities, Network Management functions and ATC.
The resolution of air traffic complexity problems is constrained by:

✓ Airspace availability limitations
✓ ATC sector capacity
✓ Operator preferences
✓ Air traffic queue management targets
✓ Network stability requirements,
✓ 4D trajectory update rules.

o **High Complexity terminal operations**
In Europe, high complexity operations would normally occur in terminal areas but may occur in other airspace.

o **En-route high complexity operations**

High complexity operations also occur in En-route so depending on the airspace and operational environment, 2D routes the can be temporary.

Preferred routing can be suspended when analysis of the pending trajectories determines areas of high potential complexity.

o **Medium/low complexity operations**

This complexity in en-route and terminal area operations prevail in areas and times of high complexity managed. The main objective is to provide enough capacity to satisfy the demand without restoring to a structured route network.

o **Human Aspects**

It has been shown that the free route operations generate an increase in the controller workload. In order to support an easy situation awareness building, sharing and maintenance within the sector team a new ATC support tools have to be studied as:

- ✓ Conflict detection tools
- ✓ Monitoring aids
- ✓ System supported coordination
- ✓ What if tools

The studies on free routing included on the route complexity management must focus on:

- ✓ Management of climbing and descending flights
- ✓ Conflict between transitioning and cruising flights in free routing
- ✓ Sectorization review to accommodate the changes in traffic flows.
- ✓ Definition of capacity and workload
- ✓ Circumnavigation of airspace reservation either restriction when it is mandatory.
- ✓ New working methods and tools have to be developed for ATC.

IOP is highly required as a support for coordination between ATSUs due to:

- ✓ No more defined coordination points
- ✓ More variable transfer geometry

o **Controller**

The performance of the operator is adapted according to the level of risk perceived. The area of performance it is characterized by silent areas (safe

areas) or turbulent areas (the loss of control is closer). Those signals are essential and should be used to manage complexity.

CHAPTER 2. RETINA PROJECT

2.1. General Concept

Nowadays, many of the technological advancements designed to improve operational safety at an airport have appeared, such as movement maps, conformance monitoring, and conflict detection. However, there is a paradox to increase the awareness of controllers by creating additional screens to show runway and taxiway layout, aircrafts and vehicle's position, etc. this can be achieved. This reduces the situational awareness by forcing it mentally.

Then Lloyd Hitchcock intruded the idea of using AR in the control tower. For instance, he suggested that AR displays could provide air traffic controllers with useful status information, such as aircraft identification, barometer settings, wind conditions and runway or gate assignments. It is known that now it can be add more information to that added by Lloyd, such as flight tags, warnings, shapes and layouts. [3]
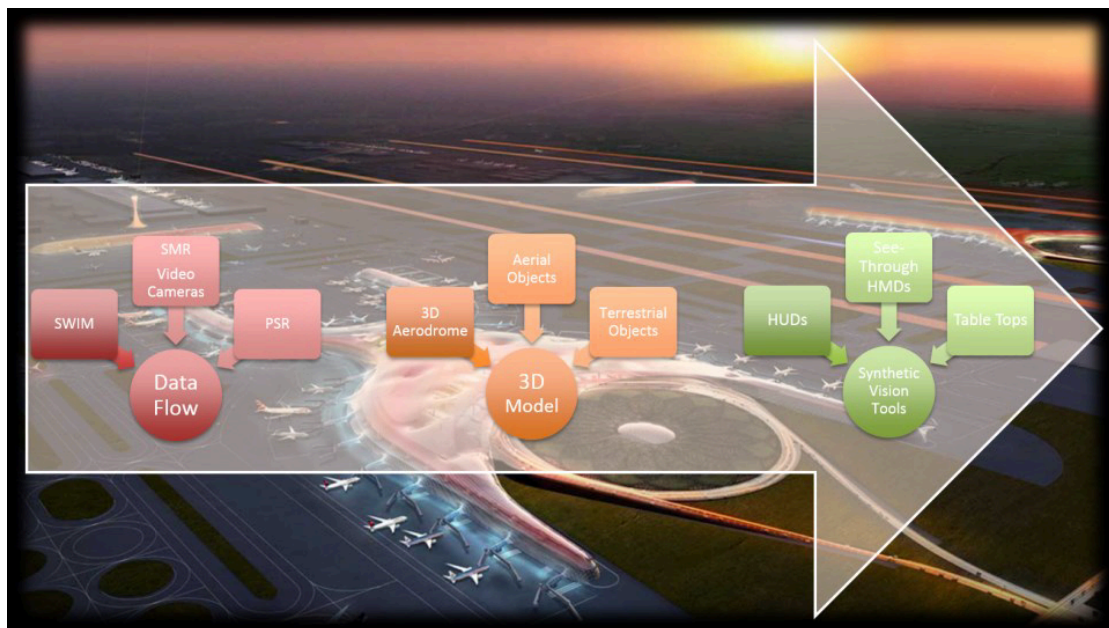

Figure 7. General Concept of Retina Project

The Resilient Synthetic Vision for Advanced Control Tower Air Navigation Service Provision (RETINA) project is one of the selected SESAR projects on High Performing Airport Operations that will investigate the potential and applicability of Virtual/Augmented Reality (V/AR). This project is based on the concepts behind tools used daily in control towers to be able to transfer all the information to the ATCO with the minimum effort and substantial benefits. Doing this, the project Consortium will investigate two different augmented reality systems. Conformal-Head-Up Displays (C-HUDs) – which, potentially, can be made to coincide with the tower windows.

See-Through Head-Mounted Displays (ST-HMD). Exists also a third tool, which is a virtual reality based Tabletop interface.

Figure 8. Partnership Retina Project

The relationship between the registered information and the user perception is a fairly important problem with this project. Due to this, RETINA project is implemented using non-intrusive, out-of-the-shelf, body-tracking sensors, such as Microsoft KinectTM.

Then the AR screens know in which position the ATCO is located its visibility, allowing the interface to display the most useful information at any time. Critical or dangerous signals that are not presently in the controller's perspective can be placed in the peripheral vision to get their attention. Overall, the information that is currently displayed on the head-down computer screens (flight tags, runway layout, intrusion warnings) could be displayed on either the see-through glasses or the head-up displays, therefore superimposed to the controller's line of sight.

Figure 9. Microsoft Kinect

The RETINA project follows the methodology based on EID (Efficient Interface Deviation). EID is a theoretical form to be able to develop an interface between human-machine in real time. EID provides controllers with the information they need to be able to solve active problems against passive monitors, so they can reduce the mental workload when an unexpected event happens and the psychological pressure is increased.

When the RETINA project can be carried out with the proposed solutions of high quality 4D information (position, height and speed over time) regardless of the climatological situation.

The efficiency of the system will be improved by reducing the average delay per flight due to weather conditions or restrictions at airports because of adverse situations or a reduction of the environmental impact of flights in terms of fuel burnt, emissions, CO_2, etc.
In short, this project gains in safety, environment, efficiency and cost reduce. [4]

Figure 10. Objectives of Retina Project

2.2. Bologna Airport

The airport of Bologna, called Guglielmo Marconi (LIPE), located in the surroundings of Bologna, Emilia-Romagna region at N 44º 31.9', E011 17.8; with an elevation of 123 feet. It has two Runways:

> **Runway 12:**
> Take-off length: 2803, Landing length: 2493
> **Runway 30:**
> Take-off length: 2803, Landing length: 2442

For aircraft of ICAO code letter D, E and F; the Runway 12 is preferential for landing, with Taxiway J as the preferential exit. And Runway 30 mainly used for landing, with backtrack and exit via Taxiway J although is the preferential runways for taking-off. [9]
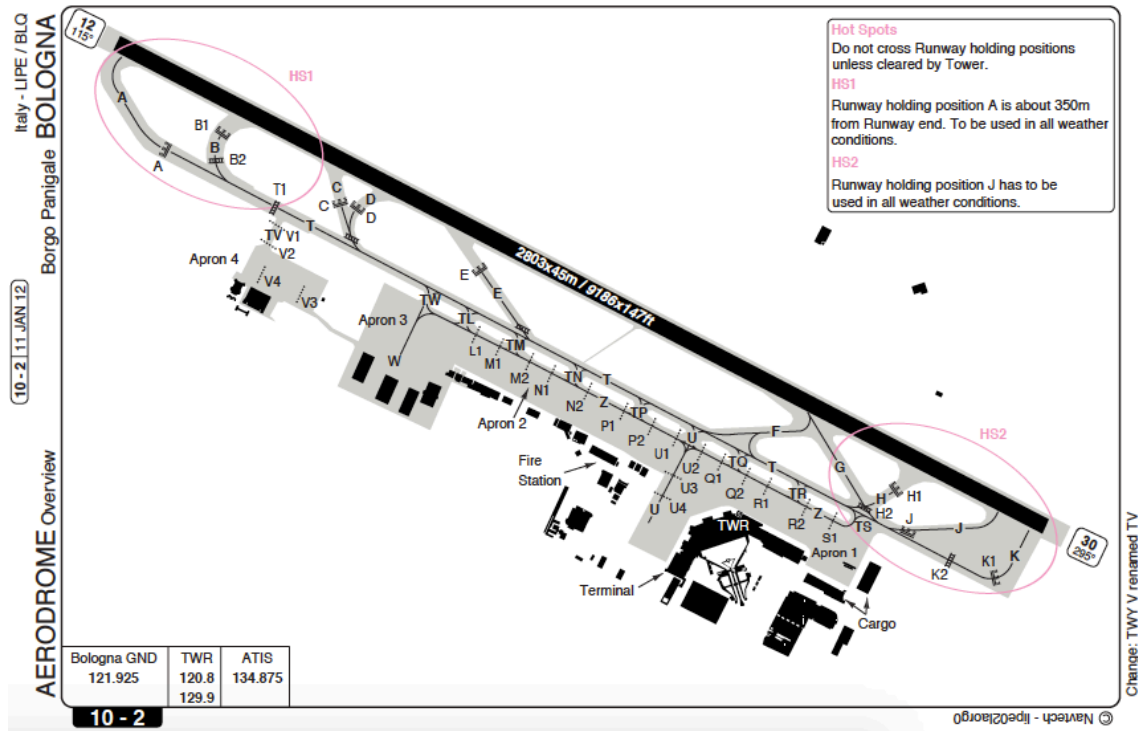
Figure 11. LIPE aerodrome overview

One of the main factors that must be taken into account is the atmospheric conditions of Bologna. Due to the precipitations, clouds, humidity and fog the visibility of the ATC from the control tower is affected.

Related temperature, the maxima that can be raised is 31 degrees and the minima is minus 0.5 degree, as is can be shown in the following graph.
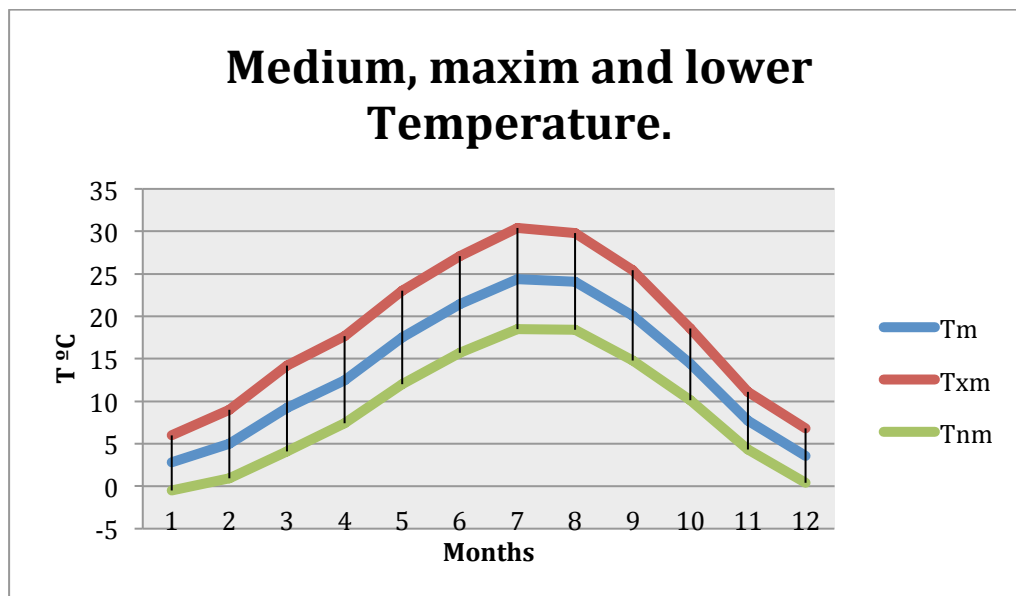

Figure 12. Temperature in LIPE aerodrome

Another important factor is the rain. About the precipitations that affect the Bologna airport it can be said that the month with a higher amount of precipitation is April with a monthly mean total precipitation (Rtot) of 72.4 mm and with a daily extreme precipitation (Rx24) of 80 mm.
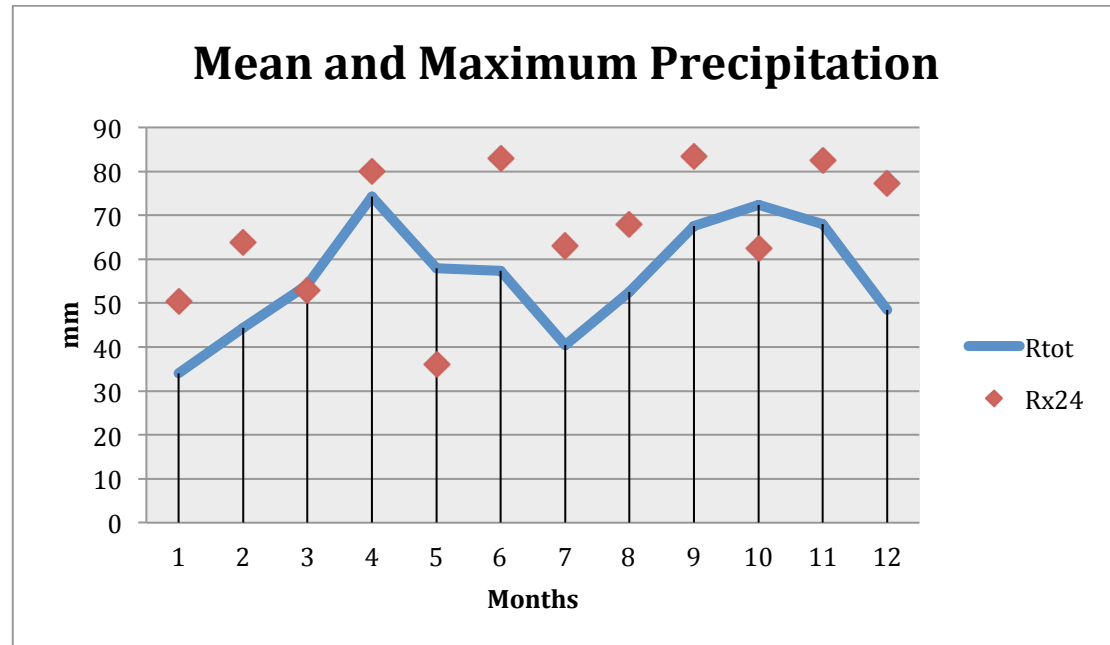
Figure 13. Precipitations in LIPE aerodrome

The relative humidity of the atmosphere is the ratio of the partial pressure of water vapour to the equilibrium vapour pressure of water at a given temperature and is one of the important factors to be taken into account when analysing the visibility of the ATC as it depends on the temperature and the pressure of the system of interest.

The month with higher humidity is November and the one with less is July.
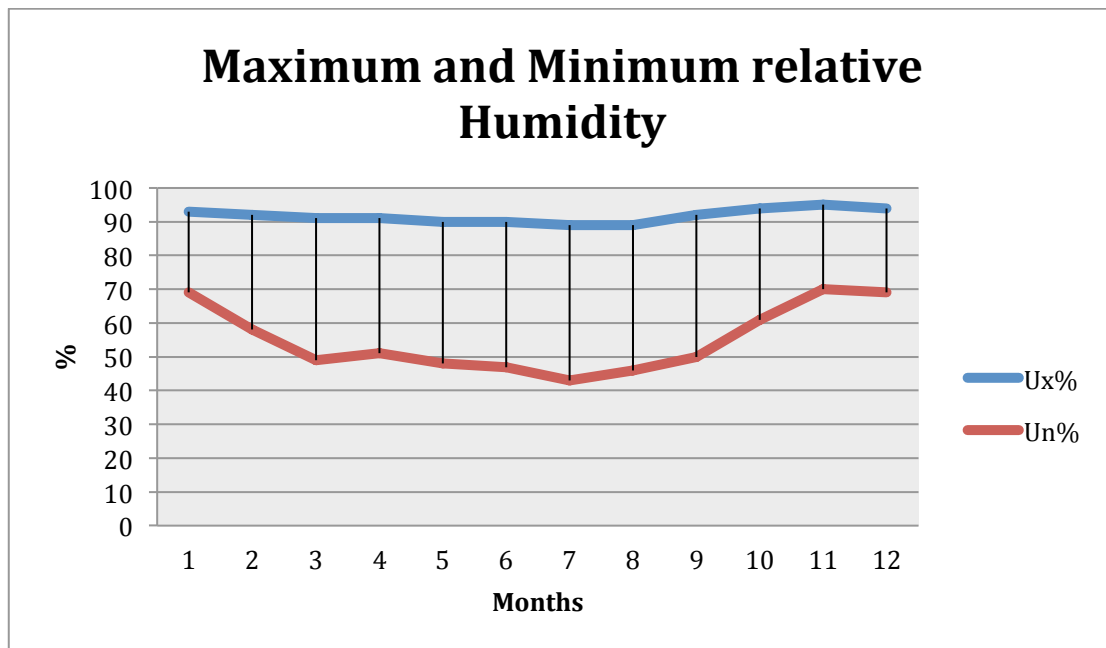
Figure 14. Humidity in LIPE aerodrome

With respect to the wind effect, it must be taken into account that, depending on the season and on the hour of the day, the direction and the intensity of the wind changes. Therefore, the following images illustrate in each season the variety of the wind due to the hour of the day.
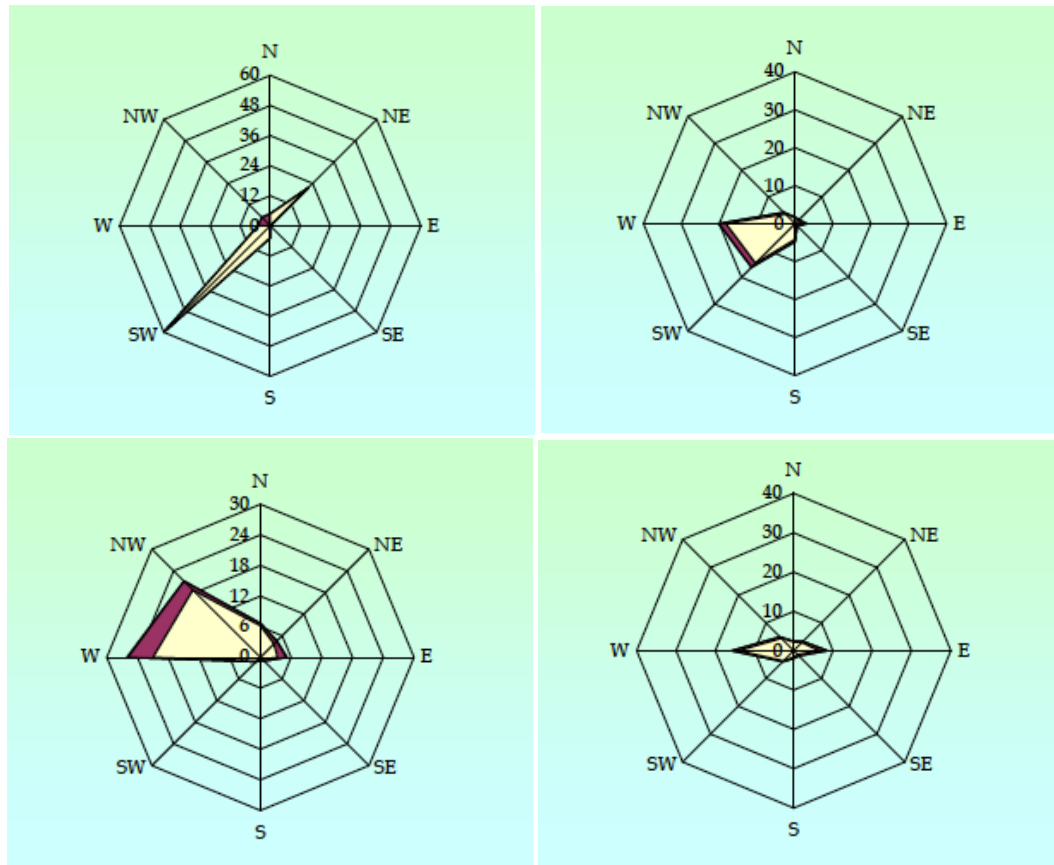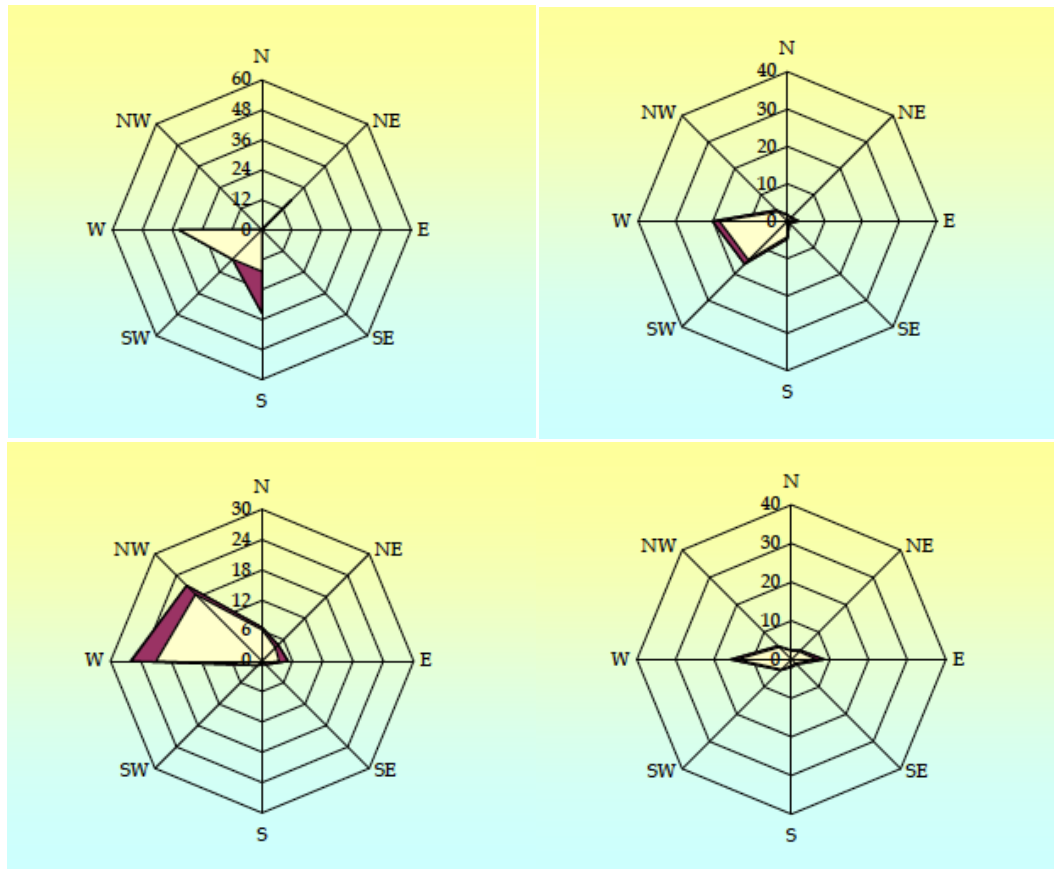
Winter

Figure 15. Wind graphic winter season

Spring

Figure 16.Wind graphic spring season
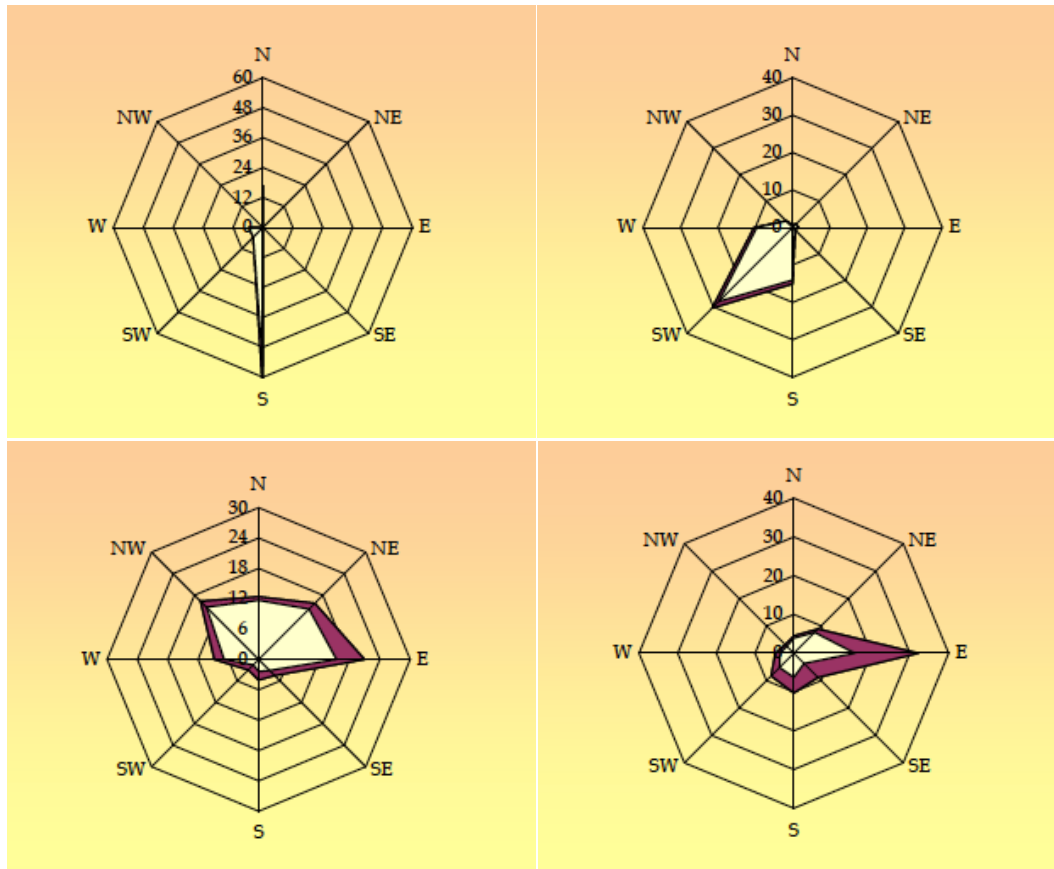
Summer

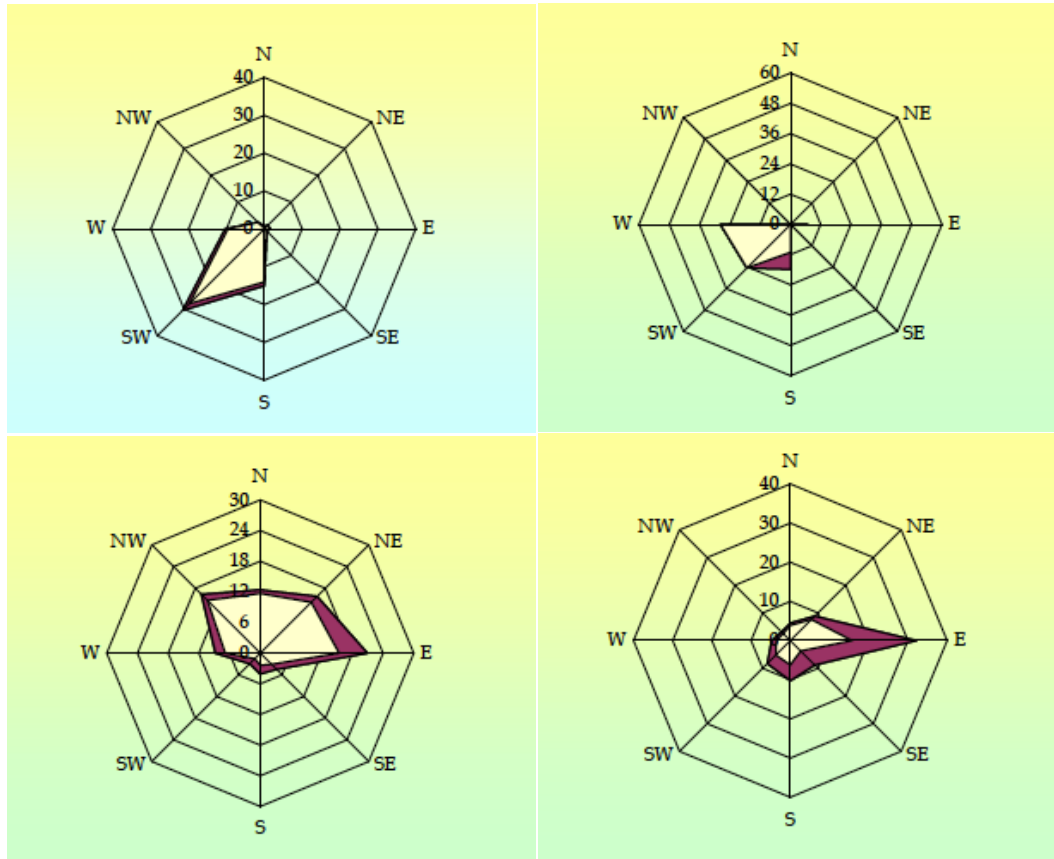*Figure 17. Wind graphic summer season*

Autumn

Figure 18. Wind graphic autumn season

The images above represent the evolution of the wind during 24 hours in the different seasons of the year represented, in 00 UTC, 06 UTC, 12 UTC and 18 UTC. This data have to be considered by the controllers when clearing off the aircrafts for landing or either taking-off.

2.3. Overlays

The possible factors that may deal the ATCO are the ones related with the visibility as climatological factors, the disposition or either location of the airplanes and the communication methods between ATCO-pilots.
As it has been explained in the previous section, the atmospheric conditions in Bologna airport are highly diverse and extreme. Therefore, it may be taken into account this factor for the surveillance done by the controller from the control tower.

From the study of the different climatological factors it can be seen that they condition the visibility. Thus, the following graphs show how the visibility varies depending on the seasons of the year, the time of the day and different atmospheric conditions as sun, rain, fog, snow, etc. [7]
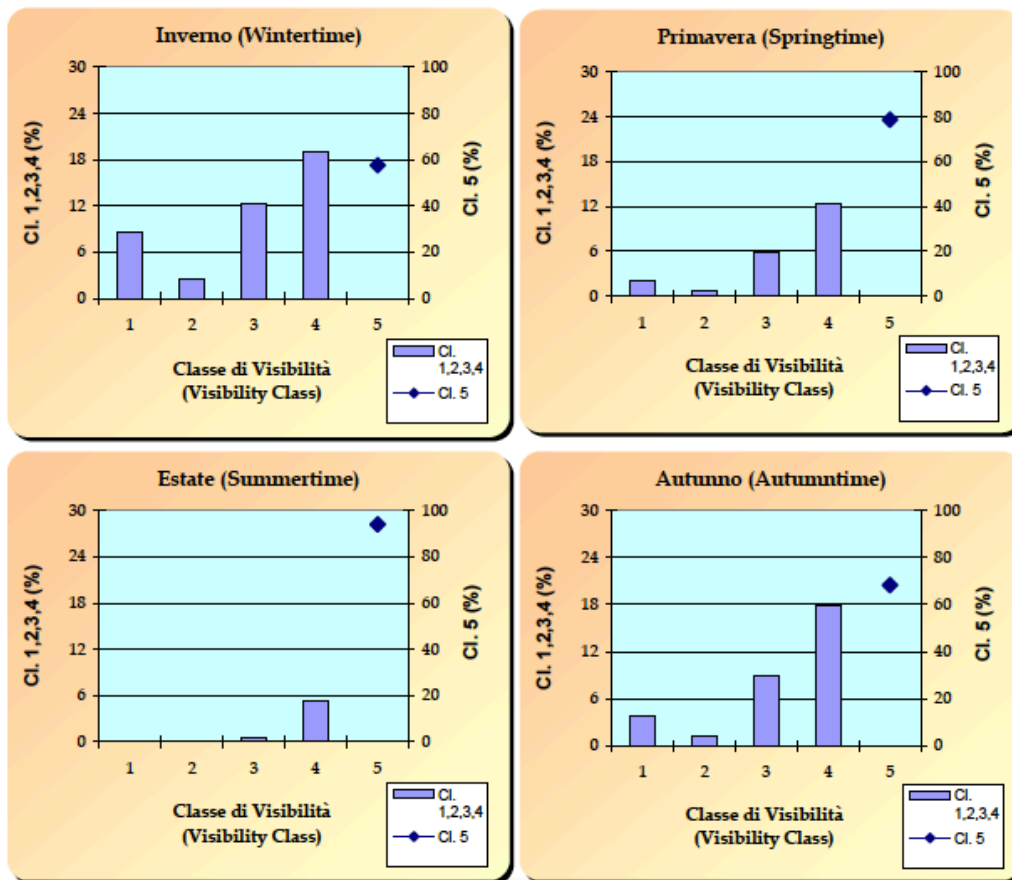
06 UTC

Figure 19. Visibility at 06 UTC

06 UTC hour					
Class	Visibility (meters)	Winter	Spring	Summer	Autumn
1	0-100	8,6	2,2	0,1	3,7
2	101-200	2,5	0,8	0,0	1,2
3	201-1000	12,3	6,0	0,6	8,9
4	1001-2000	19,0	12,4	5,3	17,8
5	>2000	57,6	78,7	94,0	68,3

Table 1. Parameters at 06 UTC

12 UTC
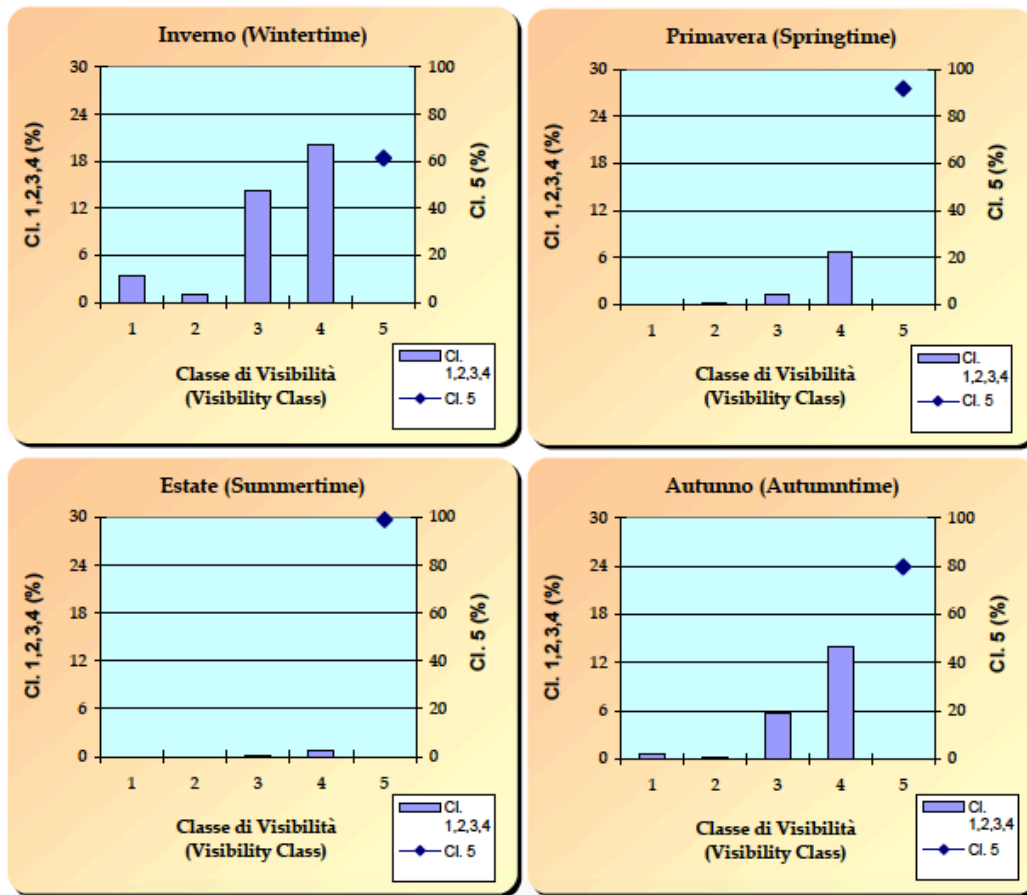
Figure 20. Visibility at 12 UTC

12 UTC hour					
Class	Visibility (meters)	Winter	Spring	Summer	Autumn
1	0-100	3,3	0,0	0,0	0,6
2	101-200	1,0	0,1	0,0	0,1
3	201-1000	14,4	1,3	0,1	5,6
4	1001-2000	20,1	6,7	0,8	13,9
5	>2000	61,3	91,9	99,1	79,8

Table 2. Parameters at 12 UTC

18 UTC
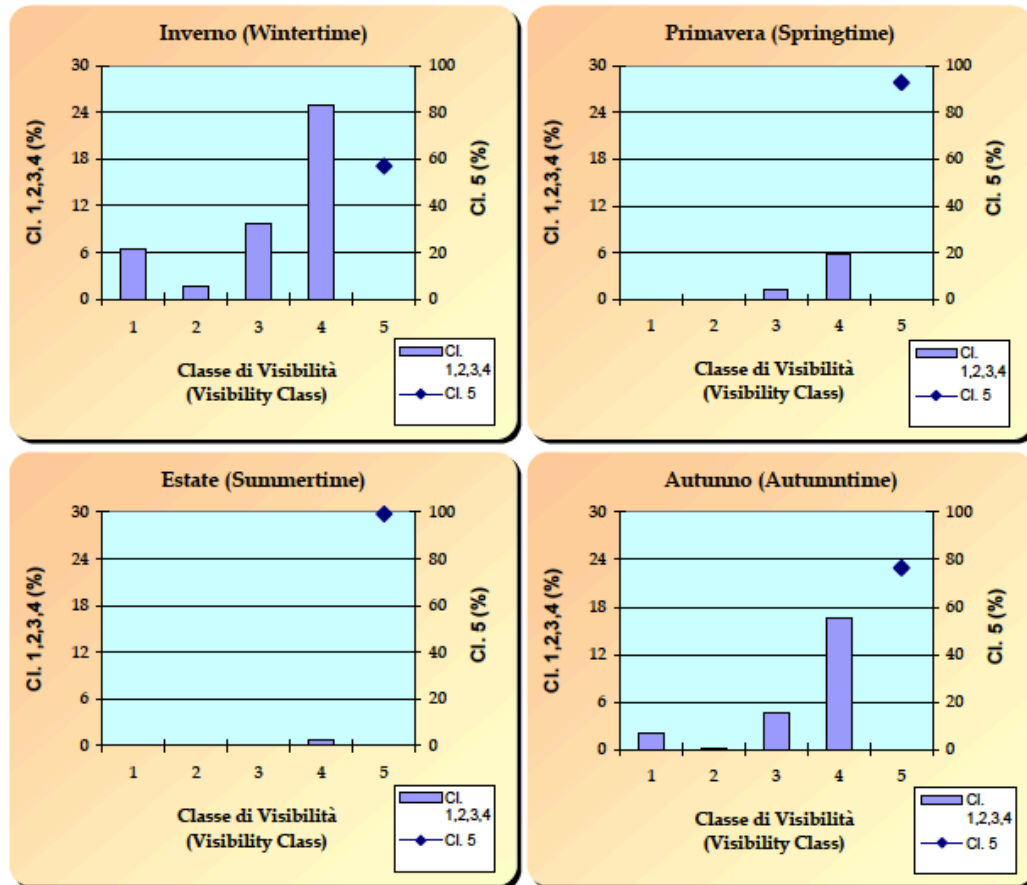
Figure 21. Visibility at 18 UTC

18 UTC hour					
Class	Visibility (meters)	Winter	Spring	Summer	Autumn
1	0-100	6,5	0,0	0,0	2,0
2	101-200	1,7	0,0	0,0	0,2
3	201-1000	9,8	1,3	0,1	4,6
4	1001-2000	25,0	5,9	0,7	16,6
5	>2000	57,0	92,8	99,2	76,6

Table 3. Parameters at 18 UTC

Figure 22. Foggy effect in Bologna Airport

Likewise the distance where the aircraft is situated from the control tower, meaning where the ATC is situated, also is a factor to be considered. Specifically in the airport of Bologna the control tower has an area of $600m^2$ and the area of control conditioned by the fog is 75 meters around.

Figure 23. Top view of Bologna Airport

CHAPTER 3. Actual ATC overlays issues

3.1. Actual ATC Concept

Air Traffic Control Operators (ATCO), is provided by those countries that have signed the Chicago treaty. They have founded the International Organization OACI/ICAO following the specific terms given by the international laws of the organization. The two principle factors that an airport requires Air Traffic Control are efficiency and safety.

3.1.1. ATC and Types

The Air Traffic Controller is the person in charge of the air traffic in the aerial space and also in the airport. The ATC must manage the planes in a safety, organized and fast way, providing relevant and useful information to the pilots, and authorizing them along their entire jurisdiction.
The aim of the ATCo is to prevent collitions between aircrafts and obstructions in the manoeuvring area.
Due to meteorological changes, huge amount of aircrafts, traffic and other not planned issues, make the labour of the ATCo complicated.
The main characteristics that a controller must have are perception and spatial projection.

Types of Air Traffic Controller

- Clearance Delivery Controller (CTA-DEL):
  It is the one responsible for coordinating and bringing the Flight Plan to the departing aircraft. At the same time supports the ground controller and the tower controller.

- Ground Controller (CTA-GND):
  It is the one responsible of guiding the aircrafts throw the Taxiway (TWY), from the gates to the chosen active runway for taking-off and landing. It can be done in a visual way, or by using the Multilateral System (MLAT) when the visibility is reduced due to meteorological conditions or because the airport is too big to manage all the runways, taxiways, and aprons.

- Tower Controller (CTA-TWR):
  It controls the airspace known as ATZ with a scope of 5 nautical miles. Responsible for the runways and the intersections; it is the one who authorizes the aircraft to landing or for taking-off and also control the lower-airspace under the visual flight rules (VFR).

The main objective is organizing in an efficient and safety way the traffic to maintain the landing and take-off airflow. It must be achieved that the congestions in the runways, due to the elevated traffic, affect in the least possible way the aircrafts and passengers.

- Approximation controller (CTA-APP):
  It controls the airspace CTR, giving priority to Instrumental Flight Rules (IFR) flight. Its responsibility area extends in a horizontal plane from the limit of the ATZ to a ratio of 10-20 nautical miles and in a vertical plane from 1500 ft. to 6500 ft. (same as FL065). Control the arrivals and departures in one or more airports using the procedures SID and STAR to prevent that the aircrafts departing and the ones arriving encounters.
  In departures, the CTA-APP controller transfers the aircrafts to the CTA-TMA controller before reaching the airspace limit, either horizontal or vertical.
  In arrivals, the CTA-APP controller transfers the aircrafts to the CTA-TWR controller when they are in the Final Approach Fix (FAF).

- Terminal manoeuvring area (CTA-TMA):
  It controls the airspace from the limit of the APP to a ratio of 50 nautical miles in horizontal axes. In vertical axes, the domain of the airspace is from FL065 to FL195.
  The main objective is to arrange in sequence the high volume of traffic, maintaining the vertical and horizontal descends separated. To achieve this, some techniques of velocity reduction are used and also the amount of landings and takeoffs are adjusted. It controls the traffic of the takeoff until the aircraft reaches the cruising altitude.

- Enroute Controller (CTA-Enroute):
  It controls the rest of the airspace. The limits are between TMA and Enroute are imposed by the states. They divide the airspace in different sections, both vertical and horizontal, to minimize the traffic impact to the ATCo and to organize in a more efficient way. This process is called sectorization.
  The aircrafts that are controlled are the ones that overfly the Flight Information Region and the ones ascending or landing at a near airport, maintaining separation between them.

- Control Area (CTA):
  It controls the volume of controlled airspace that exists in the vicinity of an airport. It has a specified lower level and a specified upper level. It provides protection to aircrafts climbing out from the airport by joining the low-level control zone to the nearest airways. [1]

3.1.2. Technology

Control manual systems

A Flight Progress Strip is a small strip of paper used to annotate important information related to flights that are under control by ATCo. The border colour of the small strips determines the direction of flights based on the cardinal points. It is mainly based on mathematical methods of distance and time performed, in order to be able to solve possible conflicts between aircrafts that are at the same flight level, considering that this airspace is under control.

Figure 24. Actual Flight Strips

In this system, the ATCo does not have a tool that allows him to automatically calculate the distance between two aircrafts or from a point given in the airspace. Moreover, there is also no possible to determine how long it will take or at what time will an aircraft be in a specific point in the airspace.
The main tool in this method is the Flight Progress Strip where the controller performs annotations with time and distance between other elements to keep the aircrafts under control. Also, it is based on reports made by pilots to pass, fly to, and fly from a point in airspace or radio navigation aids. These reports are written using symbols and numbers on the Flight Progress Strips with the purpose of determining the aircraft position.

This control system is fully analogous and depends on the capacity and speed of the controller to perform calculations and analysis to separate and arrange the traffic. It is also used in control areas where is not possible to install a radar or where radar coverage is not reliable, also is used as an initial control method where an assistant controller or procedures controller separates and organizes the traffic using this system before radar coverage enters.

Automated control systems:

Radar screen is used to maintain a safe, fast and arranged flow of aircrafts in a controlled airspace.
CNS/ATM (Communication Navigation Surveillance / Air Traffic Management) are communication, navigation and surveillance systems, which works with digital technologies, including satellite systems with various levels of automation, applied in a Global Air Traffic management system.

Basic automated systems:

They are based on systems such as primary radars, secondary radars and radio navigation aids such as Non-Directional Beacon (NDB), VHF Omnidirectional Range (VOR) and Distance Measuring Equipment (DME) that are used to get the position of the aircraft.

These systems have limitations due to the fact that they depend on ground conditions around them, like accidents and geographic elevations responsible for the transmission of electromagnetic waves fade or further obstruct transmissions have limited scope.

Other limitations, in the case of radars, are the methods of identification and height information to which is the aircraft. The primary radar only displays an echo without height information, which must be identified by the controller. However, it has an advantage, which is once the aircraft has been identified it, the echo remains on the screen until the coverage is lost. In the case of the secondary radar, it depends on the equipment aboard inside the aircraft called Transponder, which if it is switched off the echo of the screen is lost. The advantage of this is that each aircraft has a unique code to be identified automatically by the ATM systems. The code shows the actual height of the aircraft and displays information extracted from the FPL.

One of the main problems for the air traffic control is related to the large amount of traffic. Airports need to have all the information required to make landings. Many times, have been delays in landings due to miscalculation or a large number of requests for landing.

Finally, another serious problem with air traffic control is the weather conditions. Rain, snow, or ice on the runways, can hinder landings. In control centres, serious problems are the storms, because the electric shock may damage the systems, and reduce the range of the signal.

3.2. Situational Awareness

SA appreciates everything that is going on when the full scope of your task is taken into account as controlling, flying or maintaining an aircraft.

In operational terms, SA is able to anticipate near future changes and developments at the state and the dynamics of the system is understood.

SA needs to include four specific elements:

1. Extract information from the environment
2. Integrate the information with internal knowledge to create a picture of the situation
3. Direct further perceptual exploration in a continual perceptual cycle using this picture
4. Anticipate future events

The ATCo must able to manage and maintain the potential for unexpected changes in the scenario should acquire and maintain a picture of the traffic situation.

This concept is so important that an important part of the working environment of the pilot and the ATCo is designed and used to maintain it. For the ATCo includes:

- ✓ Communication (with aircrafts, ATCos and radar)
- ✓ Safety nets

Safety nets can be either ground-based or airborne, preventing hazardous situations from developing into major incidents or accidents. The main idea is to prevent collisions between aircrafts with obstacles.

The ground-based safety nets is an integral part of the ATM system, providing warning times of up to 2 minutes using primarily ATS surveillance data. Once the alert is received, ATCo is expected to assess the situation immediately and take the appropriate action. [2]

The next safety nets are typically in operation in ATM automation systems:

1. Short Term Conflict Alert (**STCA**), assists ATCo in preventing collision between aircrafts by generating an alert of a potential or actual infringement of minimum separation.
2. Area Proximity Warning (**APW**), warns ATCo about the unauthorised penetration of an airspace volume by generating an alert of a potential or actual infringement of the required spacing to that airspace volume.
3. Minimum Safe Altitude Warning (**MSAW**), warns ATCo about increased risk of controlled flight into accidental terrain by generating an alert of aircraft proximity to terrain or obstacles.
4. Approach Path Monitor (**APM**), warns the controller about increased risk of controlled flight into accidental terrain by generating an alert of aircraft proximity to terrain or obstacles during the final approach.

The main contributory factors of these situations are due to:

- ✓ Interruptions and distractions
- ✓ The use of local language on a radio frequency used by pilots who are not familiar with it
- ✓ The workload of the ATC or the pilot.
- ✓ Poor radio discipline

CHAPTER 4. Modelling Overlays

As it has been explained in the lasts chapters, due to the awareness situations that it can have in the Airport of Bologna and the climatological adversities situations that the controllers have to deal with; we have worked on the representation of different possible scenarios.

4.1. Scenario Description

A scenario is the representation of possible situations that might happen in reality taken into account all type of factors, adverse and favourable ones.

4.1.1. Airport

At first it is important where these scenarios are represented. Airport of Bologna is the airport model chosen for this representation.
Some relevant information must be bear in mind as the location of the control tower, for computing the distance between the position of the ATCo and the other significant elements of the airport as the runway, the taxiway, the passenger's terminal, the parking areas, etc.

From the control tower to the threshold of runway 12, the runway used for landings, is 1760 meters; and the distance to the threshold of runway 30 (priority for take-off) is 500 meters. Both distances are shown in the images below. [5]
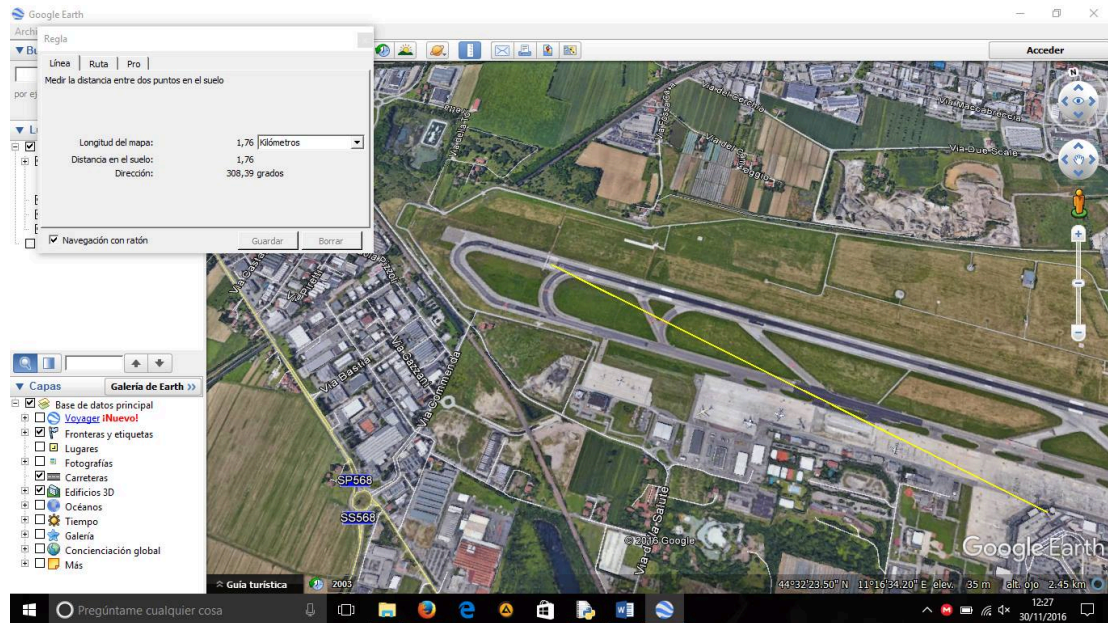
Figure 25. Distance to threshold of Runway 12
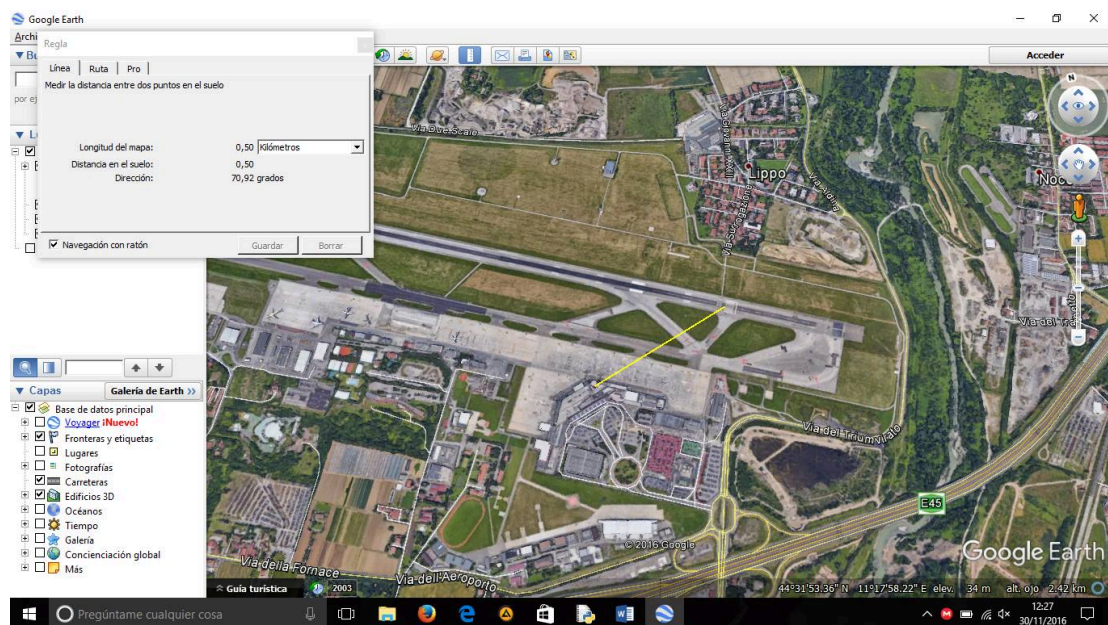
Figure 26. Distance to threshold of Runway 30

Likewise the distance from the control tower to the Exit Taxiway J is 750 meters as is the one preferential to be used. The distances of Exit Taxiways C, D, E, F, H are not computed due to they don't have to be used. On the other hand, the distance to Taxiway "J" have to be computed as it is the most used by four engines aircraft; so the maximum distance is 1900 meters and the minimum distance is 160 meters. [8]
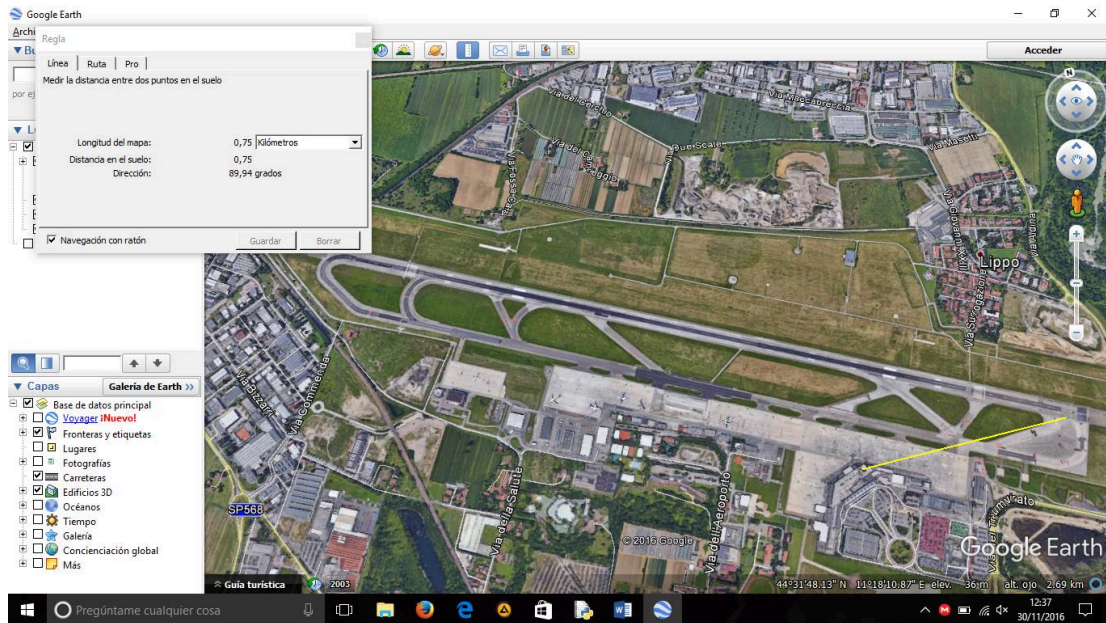
Figure 27. Distance to Exit Taxiway J
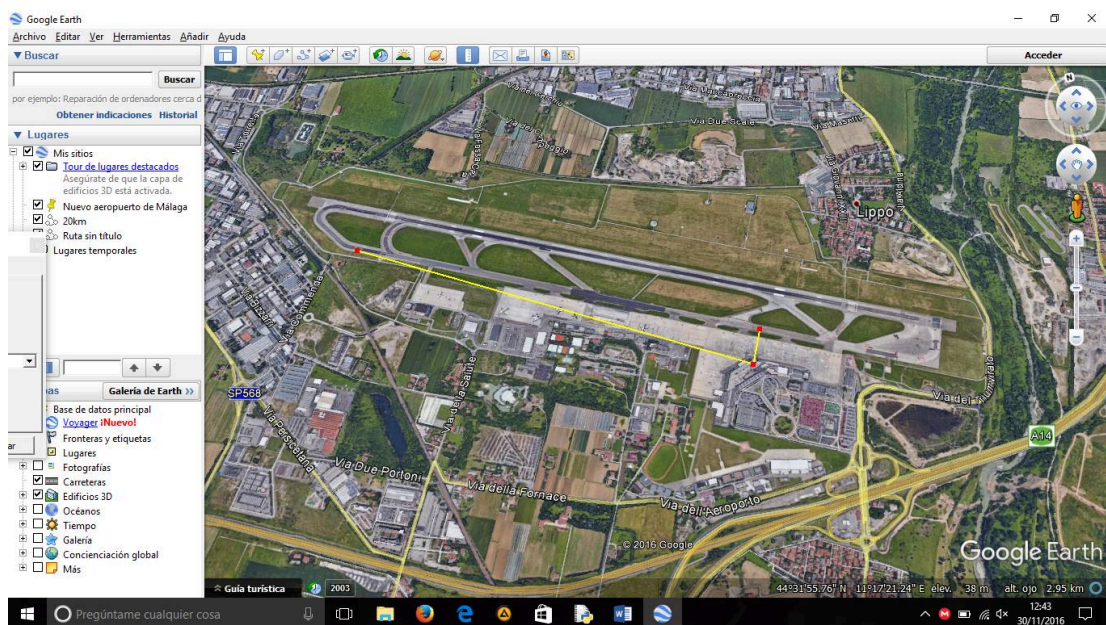
Figure 28. Maximum and minimum distance between Control Tower and Taxiway

Consequently the parking areas are important for the ATC as they have a lot of movement. So, considering that the Airport of Bologna has four aprons and all of them have parking areas, the distance to the control tower is an important factor. [6]

As the image shows, these are the 4 aprons with their corresponding position of parking. The distances are the following:

- ✓ Distance from control tower to apron 1: 30 meters
- ✓ Distance from control tower to apron 2: 500 meters
- ✓ Distance from control tower to apron 3: 1000 meters

✓ Distance from control tower to apron 4: 1400 meters
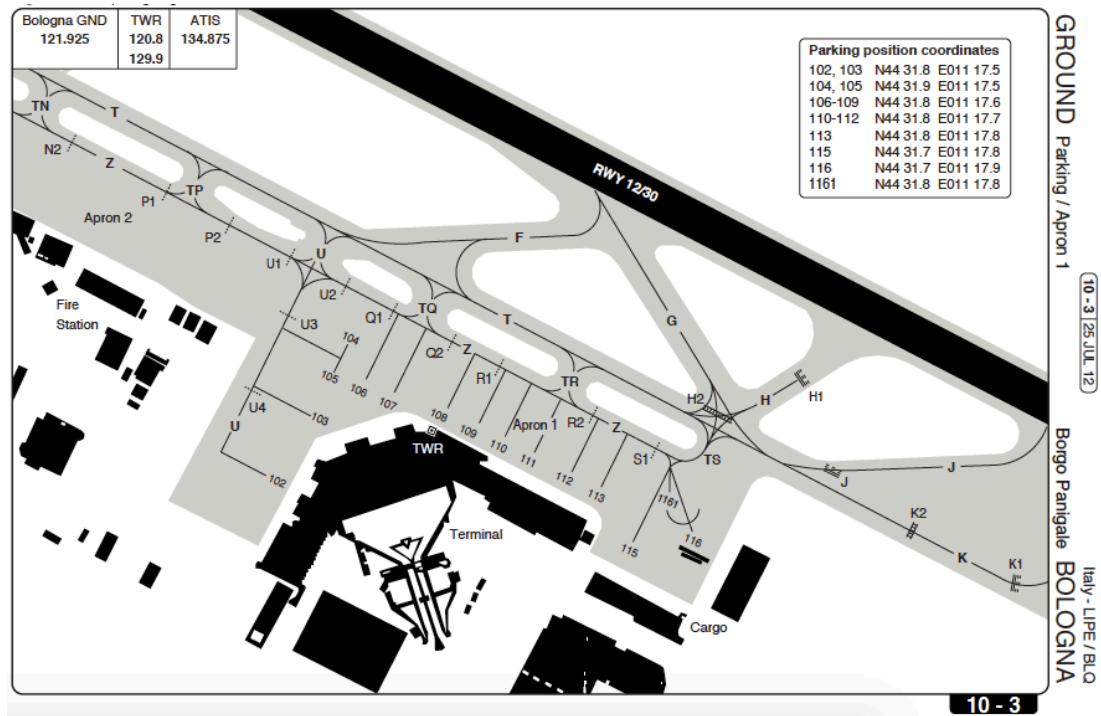
Figure 29. Apron 1 of Bologna Airport
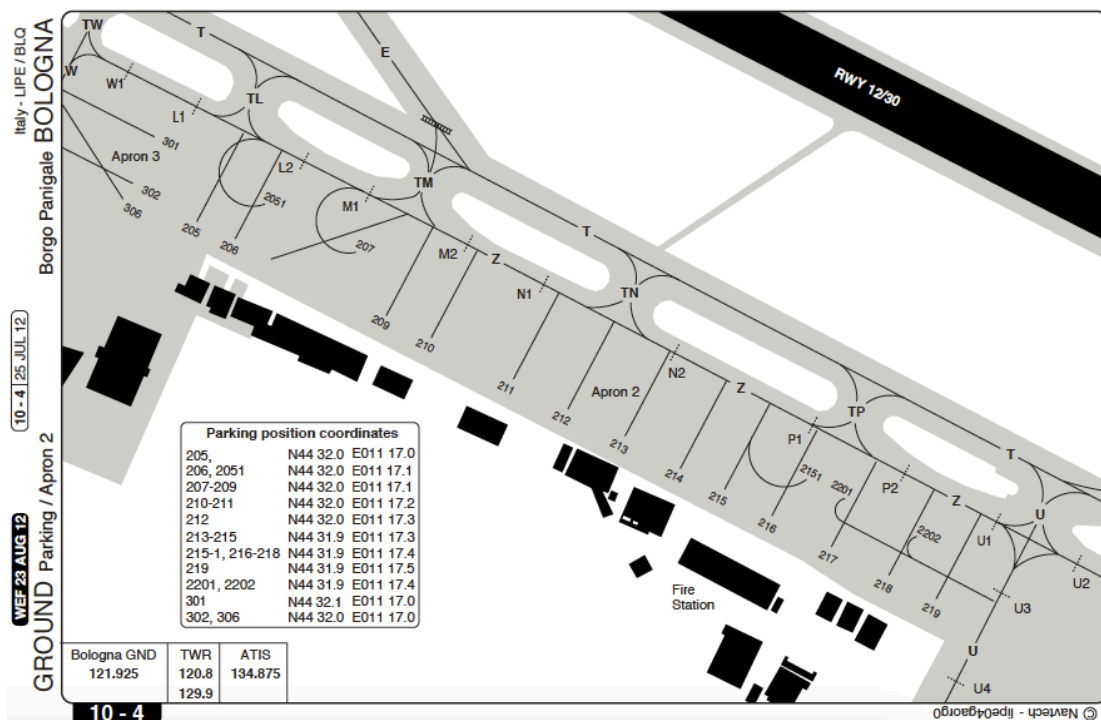
Figure 30. Aprons 2 and 3 of Bologna Airport
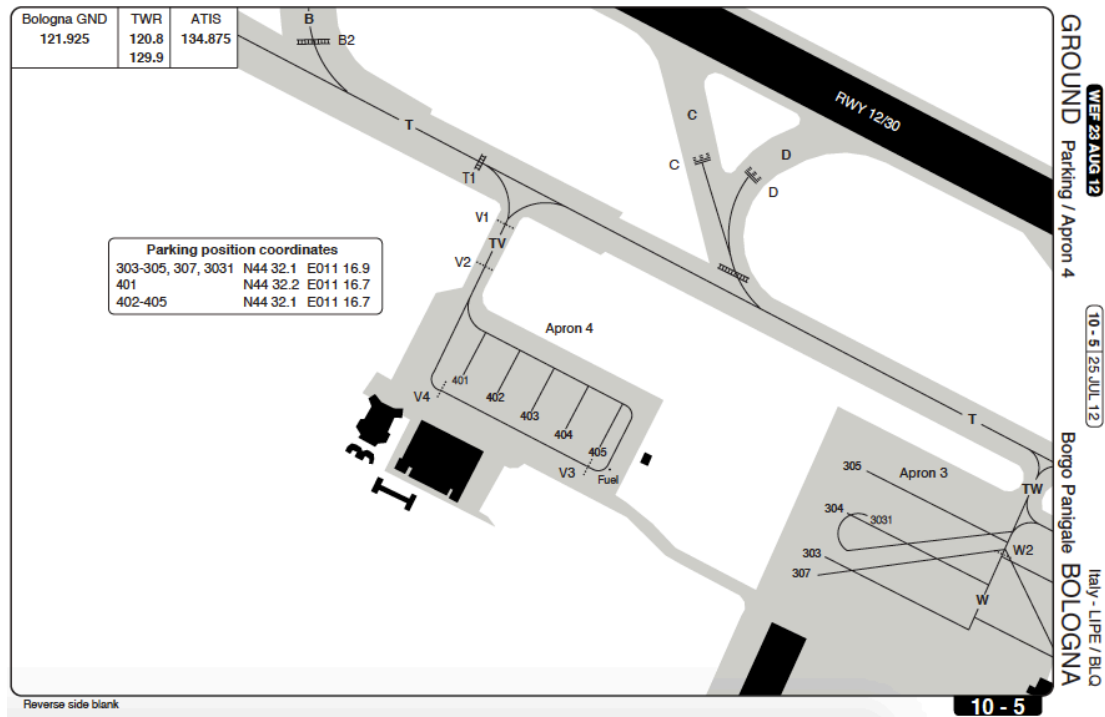
Figure 31. Apron 4 of Bologna Airport

4.1.2. Actuators

A second important factor on the scenario is the actuators. The aircrafts are the ones defined as actuators.

The three important traits are:
- ✓ Number of aircrafts
- ✓ The model of the aircrafts
- ✓ The location of them in the scenario

Due to there are different significant parts of the airport, we decided to place one aircraft in each significant part. So one aircraft can be on the runway, another on the exit Taxiway or either on the Taxiway and finally thelast one can be placed on one of the aprons.

On the other hand as there is a huge amount of different types of aircrafts that can embrace the airport of Bologna, we decide to represent two different types of aircraft, a narrow body and a wide body to be more realistic.

4.1.3. Atmospheric conditions

As different climatological factors condition the visibility, it must be done a classification of the possible scenarios due to these climatological adversities:
- Good visibility (sunny day)
- Poor visibility (foggy, cloudy day, rain, snow).

4.1.4. Flight Progress Strip and Frame models

The airport, the actuators and atmospheric conditions condition the design of the visual representation of the frame and the flight strips. So the design of them must be adjusted and elaborated in a way that the adverse factors that reduce the visibility of the controller, does not affect as much as it does nowadays.
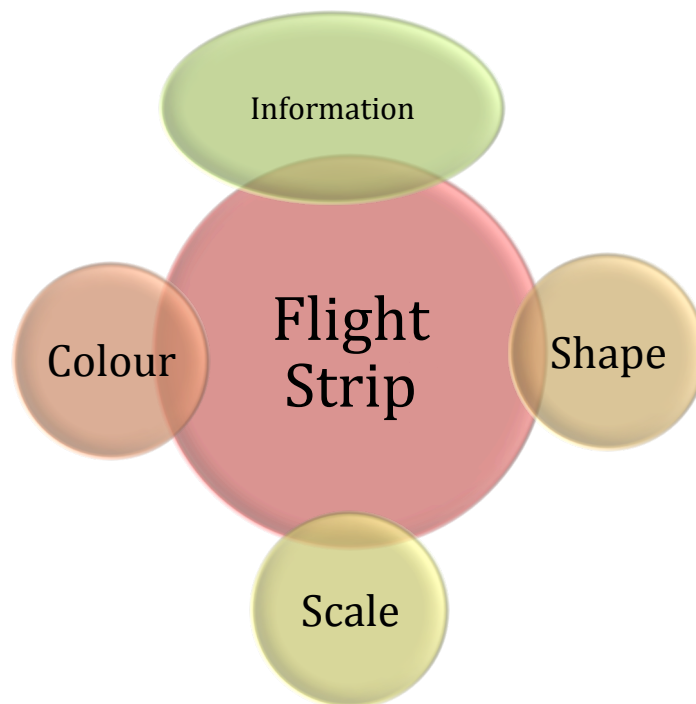
Figure 32. Factors of the Flight Strip
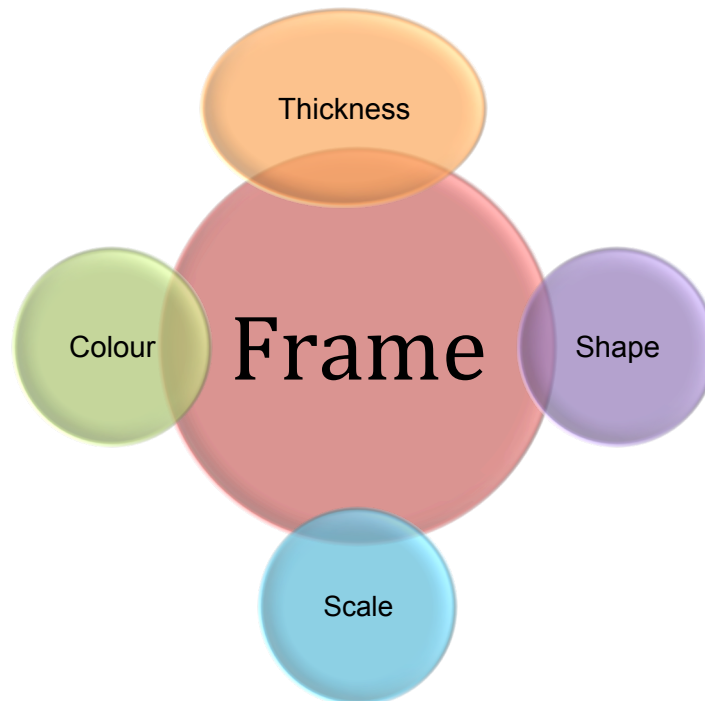
Figure 33. Factors of the Frame

The text label that contains the flight information must be shown in different colours depending on the visibility of the scenario. Also the size of the label must be scale according to the position of the aircraft from the ATCo to be readable.

Moreover the frame of the aircrafts might be scale and coloured according to the position and the visibility of the scenario. In short, the frame must be designed as the Flight Progress Strip.

Flight Progress Strip Information

The information that must be display in the label is the same that now receives the ATCo in a strip of paper. Due to this, we have chosen the most relevant information for that the controller. This information must be displayed on the screen next to the aircraft. [10]

Figure 34. Information contained in the Flight Strip
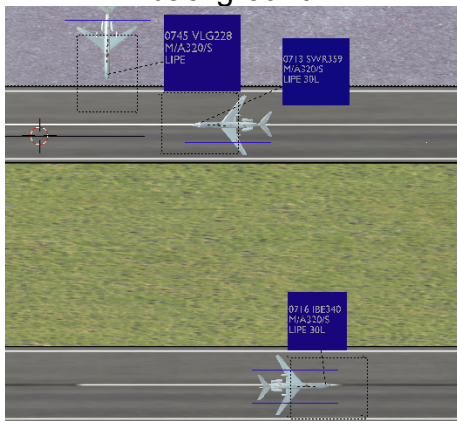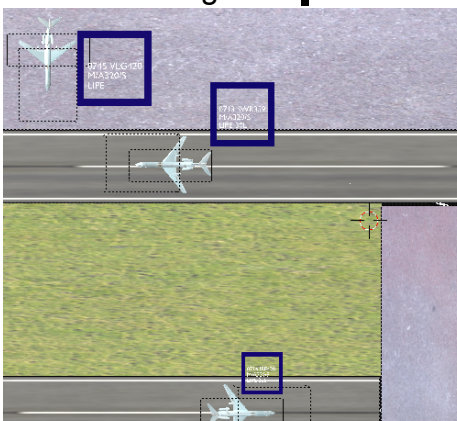
The image above shows the following information (from left to right):

✓ 0713 → Slot time (the ideal time for us to get a flight airborne to fit with airspace regulation).
✓ SWT359 → "SWT" is the abbreviation of the airline and "359" the identification of the flight.
✓ M/A320/S _ 7030/ I → "M" refers to the category of the aircraft (medium) that is important for getting the right separation distance, "A320" the model of the aircraft, "7030" is the transponder code and "I" means that the flight is operated under Instrument Flight Rules (IFR).
✓ LOK → holding points around the airport.
✓ R → possible restrictions that might be along the route.
✓ CALL → Where a particular note can be attached.
✓ LSGG → ICAO location indicator.
✓ 27L → the runway the aircraft departs from. "27" is the magnetic heading of the runway and "L" being the left hand runway.
✓ MID 3G → "MID" is the abbreviation for Midhurst and refers to the SID the flight take.

4.2. Experimental Plan

At this point we will combine different actuators with different scenarios in several atmospheric situations, to choose at the end, the best combination for each awareness situation.

For the overlay Flight Progess Strip it has been designed two possible concepts changing the three main factors. After that, each concept should be test with different climatological situations.

	Concept 1	Concept 2
Shape	Rectangle with coloured background	Rectangle with transparent background 5
Colour	Blue/Red	Blue/Red
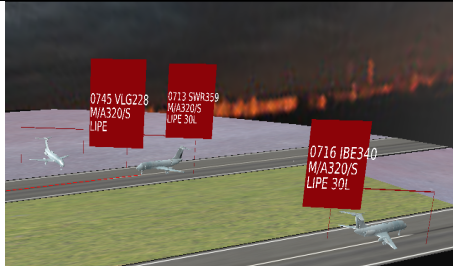
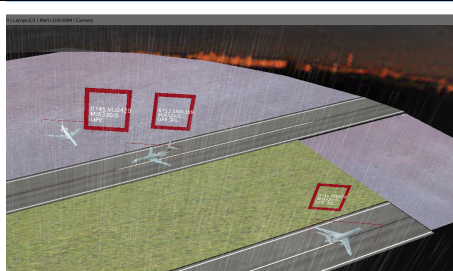|		
Scale	Constant scale regardless the aircraft position	Scale with the aircraft position

Table 4. Actuators on Concept 1 and Concept 2

Table 4 descrives the factors modified on the two concepts that are shown in the images below.

Firstly it must be said that three aircraft compose the main scenario, two of them are dynamic (running in the Runway either the Taxiway) and one is static situated on the apron as a parked off-stand. The distance between the control tower (represented as the "Camera" of the scenario) and the Runway/Taxiway threshold have been projected in a way to get a more realistic view of the ATCo in the simulation. The dimensions are described in the section 4.1.

So, to each aircraft it has been applied one of the two concepts listed in the previous table.
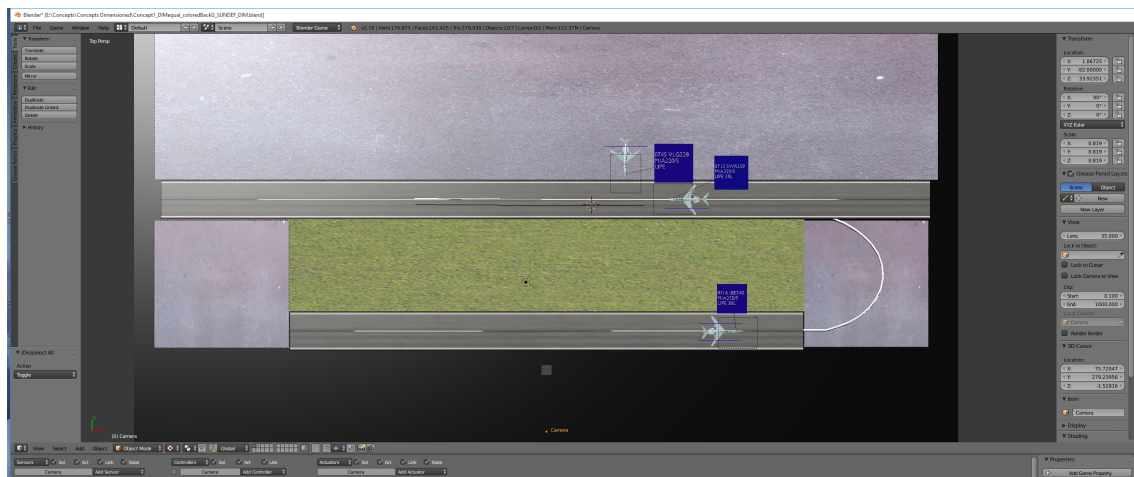
Figure 35. Scenario Concept 1
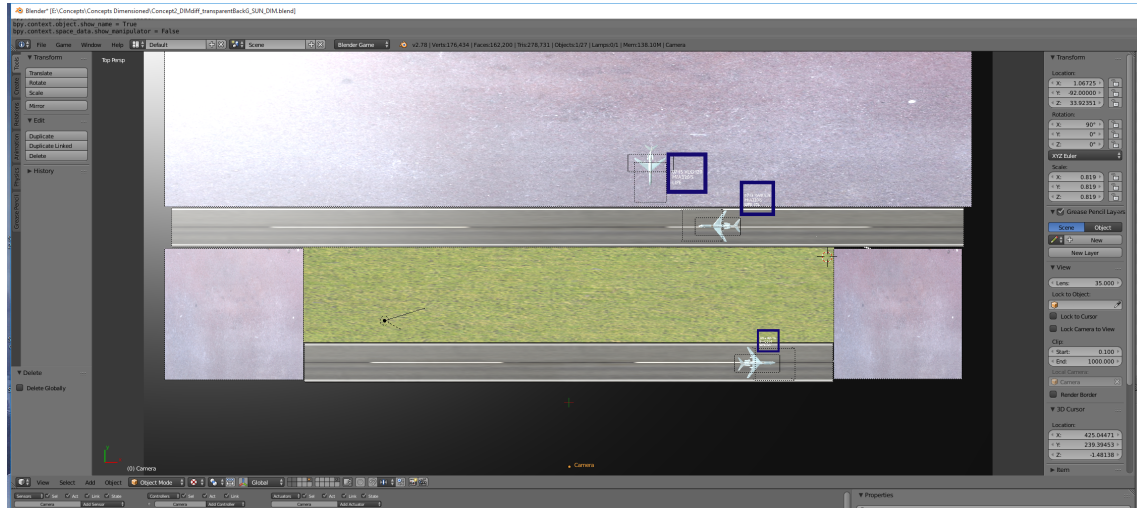
Figure 36. Scenario Concept 2

As it is shown, the general on both applied concepts is quite similar, remaining the aircraft on the same position, with same dimensions to compare both concepts in an easy way. The main difference is the Flight Progress Strip that contains the information of the aircraft. In one concept it appears with coloured background and in the other with a transparent background. Also the dimensions of this label are computed to be constant in one scenario regardless the distance with the ATCo and in the other concept the flight information is dimensioned according the aircraft position and the perspective of the ATCo. All these concepts are explained step by step in the Annex.

In addition to this, different climatological situations have been represented on the simulation to study how visibility is reduced and how applying one of the two concepts can solve this reduction. It should be choose which one is more efficient in each situation.

For this reason, we have computed three climatological factors as:

- ✓ The sun for a good visibility situation
- ✓ The foggy/cloudy and the rain for a bad visibility situation.

1. For the Sun effect it has been taken a more powerful lamp like "Hemi" mode. At the same time for the landscape of the sky has been used as a texture image for the scenario to represent a clear up day.

2. The rain effect is formed by a group of different "Empties" that represents in a symbolic way the behaviour of the clouds. Falling from them several transparent planes with the rain texture until they reach the three planes situated on the surface of the scenario where the rain collides with the ground.

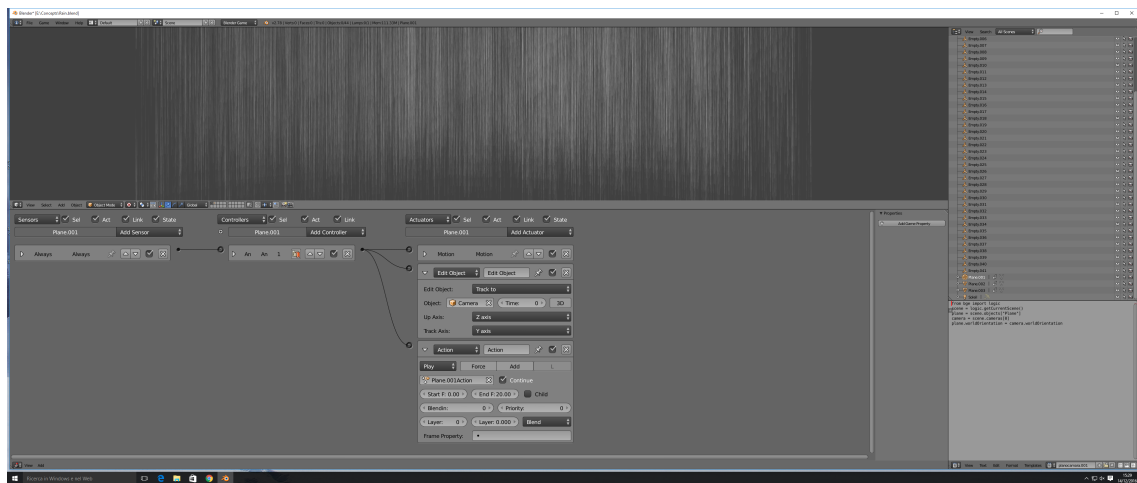*Figure 37. Rain Simulation*

Figure 38. Functions used in "Logic Edit Mode" to represent rain effect

3. For the foggy effect it has been created at first a single transparent plane, with high intensity and fully transparency to represent the texture added (an illustration of fog), and after that the duplication of this plane has been done to get a layer of fog above the surface and simulate in a realistic way the climatological situation.
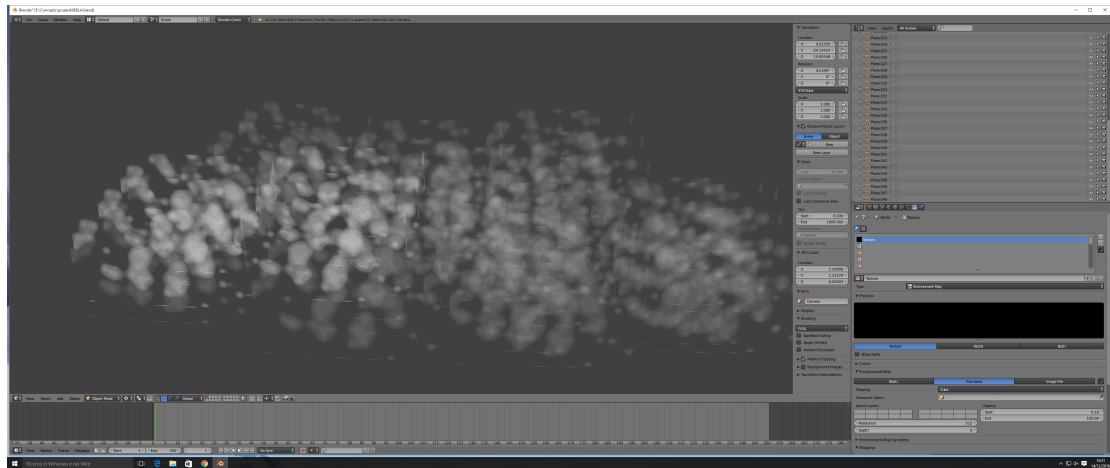
Figure 39. Fog Simulation

Keeping on with the representation of the different scenarios with the combination of the three climatological situations and the two concepts described preciously, six possible situations have been represented, two for each climatological situation.

4.2.1. Sunny Scenario Representation

The following images represent the Sunny scenario with the two concepts applied.

Figures 40 and 41 are the overview of the scenario, where it is verified that the plains contains the aircraft information and also the frames of each aircraft faces the camera (ATCo representation) when the program runs.
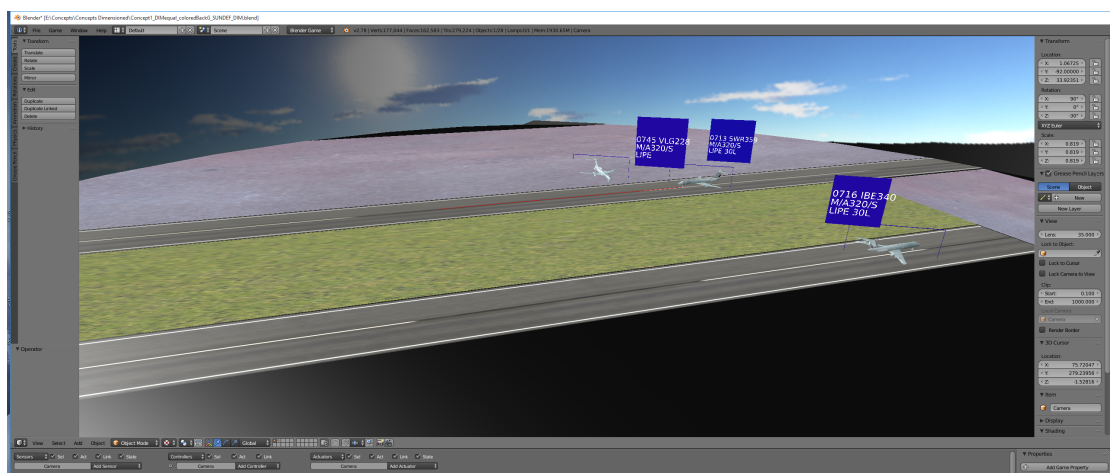
Figure 40. Top View of Sun Scenario representation in Concept 1
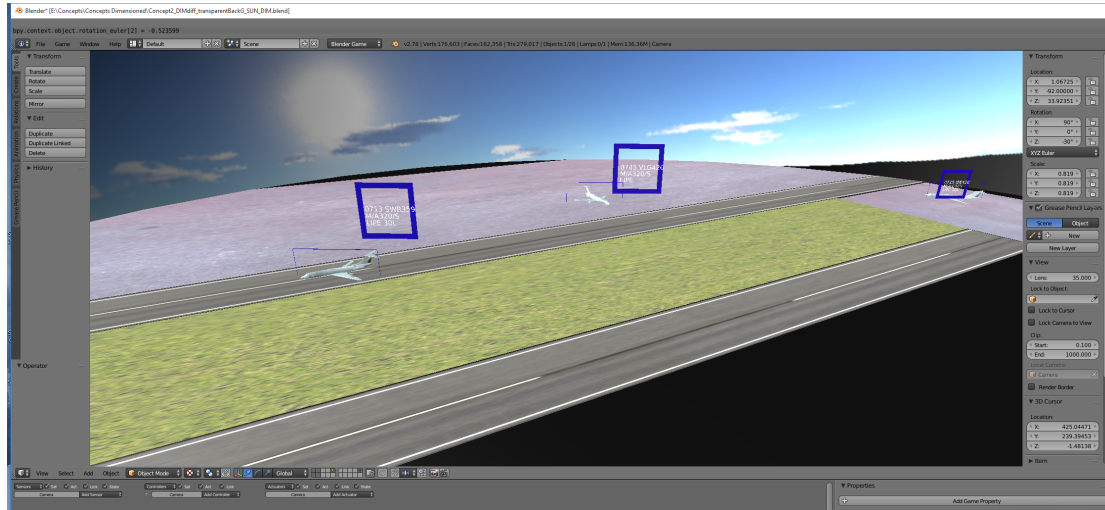
Figure 41. Top View of Sun Scenario representation in Concept 2

As it is seen in concept one, as the dimensions of the text remains equal, is more readable the text information for the ATCo than the text shown in concept two (Figure 41), due to it is not resize with the aircrafts distance and position from the ATCo.

Trying to represent ATCo place, the image below show the vision from the control tower and the real distance and visibility of the aircrafts in the whole airport (Runway, Taxiway and Parking areas).
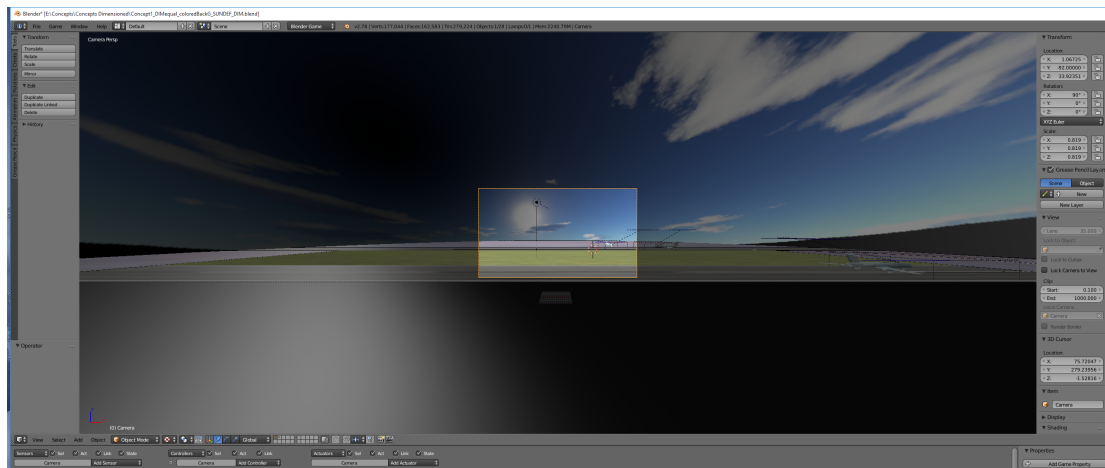
Figure 42. ATC view of Sun Scenario

From this point of view is more than evident that the transparent background in not efficient for our purpose due to it is unreadable by the ATCo. At the same time it is impossible to control the aircrafts moving on the surface.
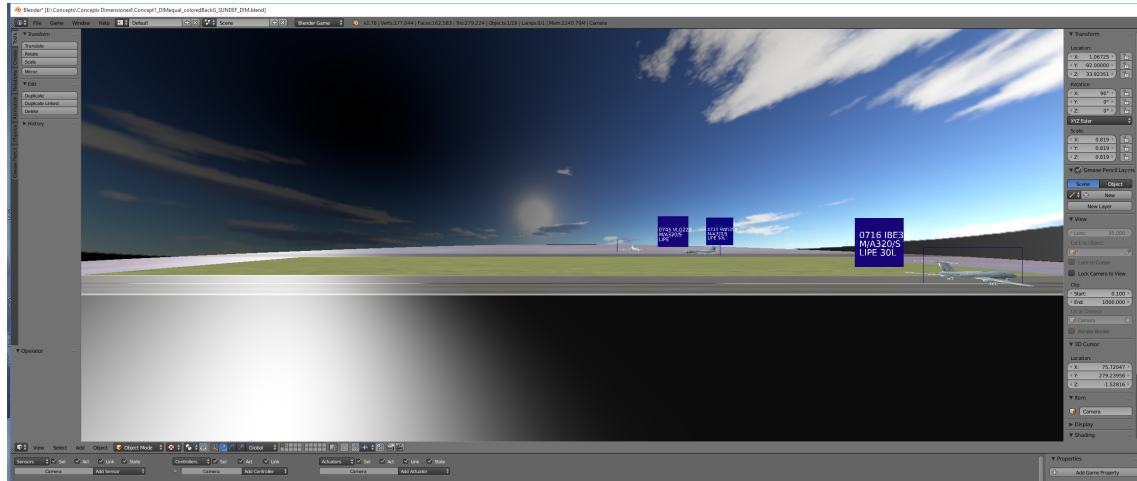
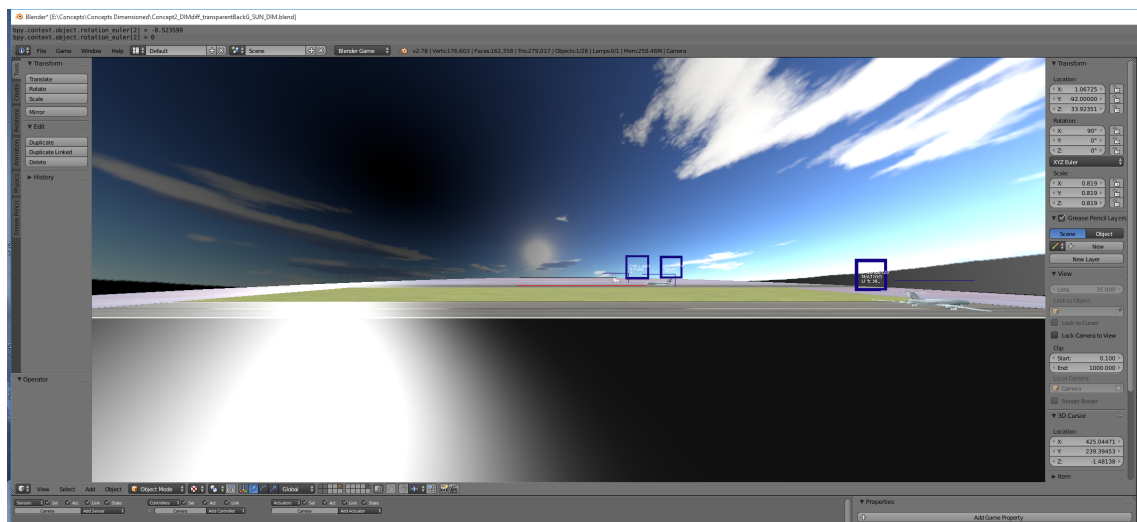*Figure 43. ATC view of Sun Scenario representation in Concept 1*

Figure 44. ATC view of Sun Scenario representation in Concept 2

For these reasons, although it is a good visibility situation, the best solution that has been coming up is to apply a coloured background for the text information and a constant dimensions size. Likewise the dark blue colour applied to highlight the factors is appropriate for this situation.

4.2.2. Rainy Scenario Representation

As in the section 4.2.1, the first two images are the overview representation of the two concepts scenario with rain condition applied. As it is seen on the images below the main difference is that the frame and the plane that contains the aircraft information is coloured in red. Due to it is considered a low visibility condition; the highlight of the aircrafts must be more garish.
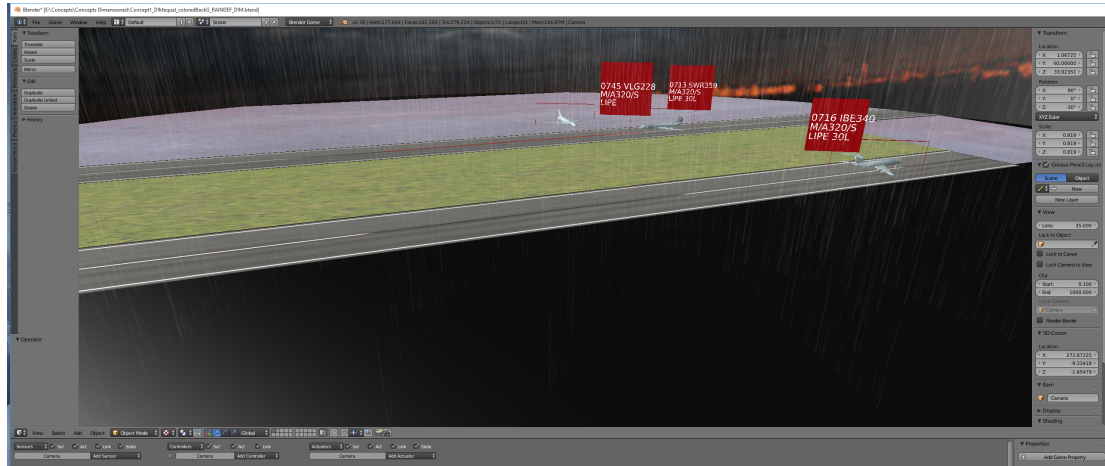
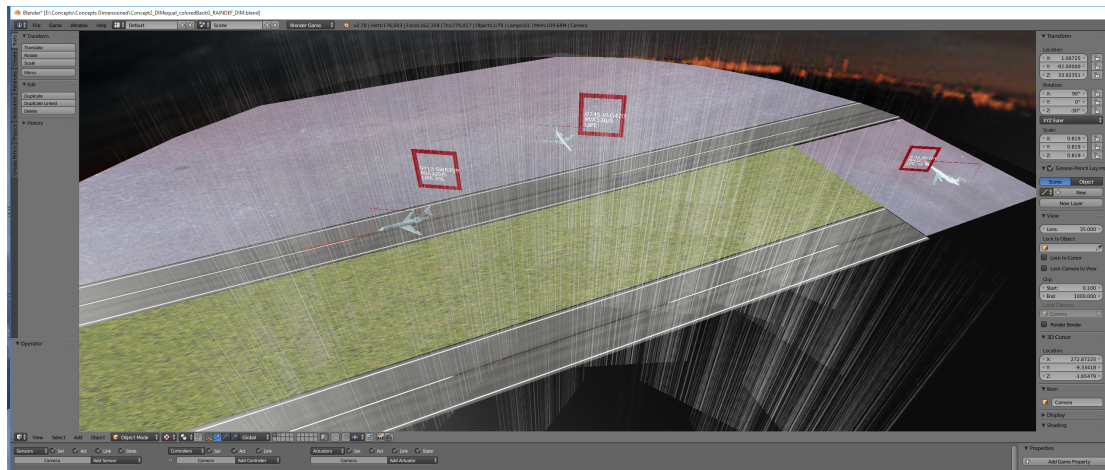*Figure 45. Top View of Rainy Scenario representation in Concept 1*

Figure 46. Top View of Rainy Scenario representation in Concept 2

Trying to represent ATCo place, the image below shows the vision from the control tower and the real distance and visibility of the aircrafts in the whole airport. Comparing with the sunny climatological situation the visibility in this scenario is reduced because of the light reduction in the scenario and also, the rain effect reduces in an important way the visibility of the aircraft information.
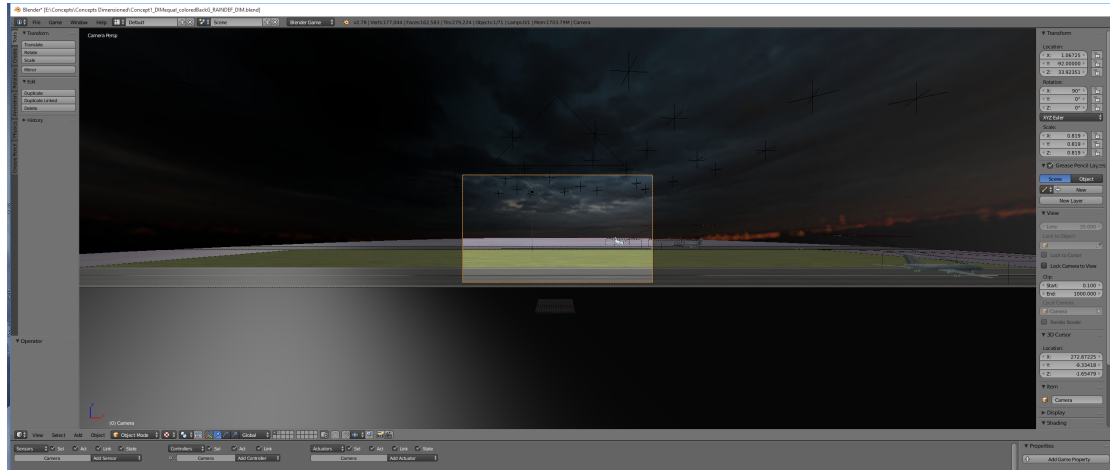
Figure 47. ATC view of Rainy Scenario

Looking throwing the scenario representation a constant dimension of the information shown continue being the best option. Although it is important to has a slight difference of size between two aircrafts in different positions to be easier to situate and control by the ATC.
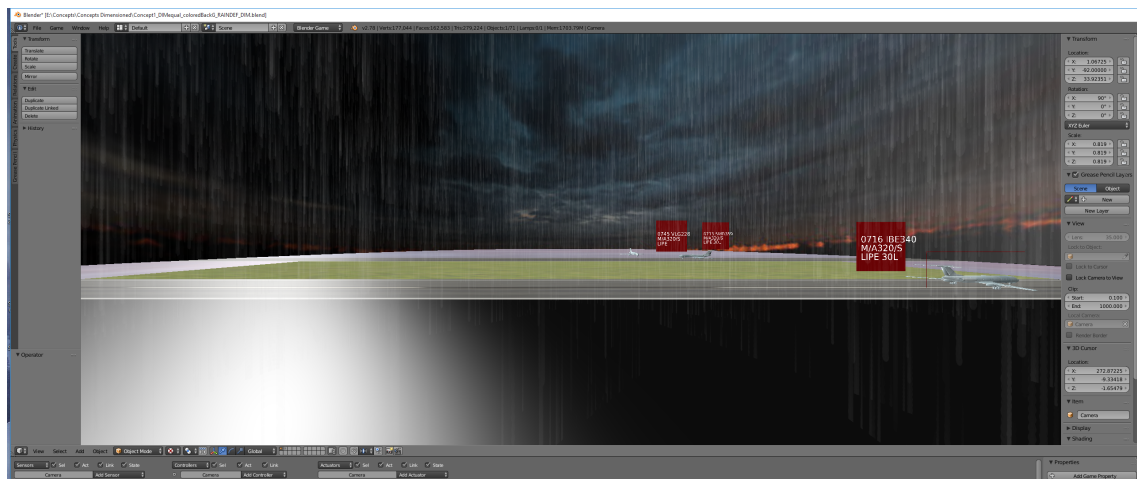

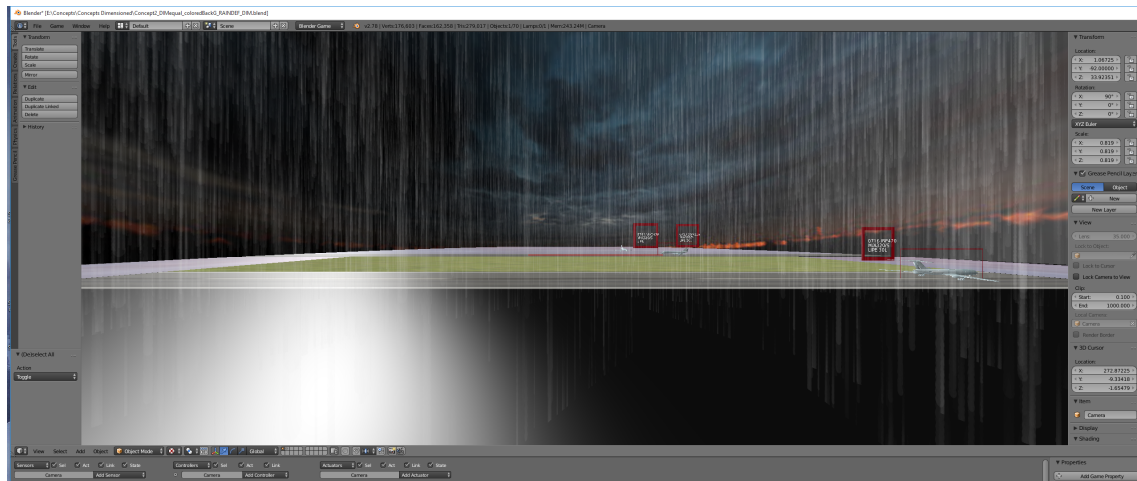*Figure 48. ATC view of Rainy Scenario representation in Concept 1*

Figure 49. ATC view of Rainy Scenario representation in Concept 2

In relation with coloured or transparent the background, due to the overview is darker a transparent background applied on the text is not as bad as applied in the sunny climatological overview.

However it is more visible to have a coloured background taking into account that red colour is very striking.

In conclusion for this representation both backgrounds will be useful and efficient and a constant dimension size is the best option.

4.2.3. Foggy Scenario Representation

This section study the overview representation of the two concepts scenario with foggy effect applied. The frame and the plane remains with the same red colour as it is considered a low visibility situation for the ATCo and both, the flight information and the aircrafts have to be distinguish.
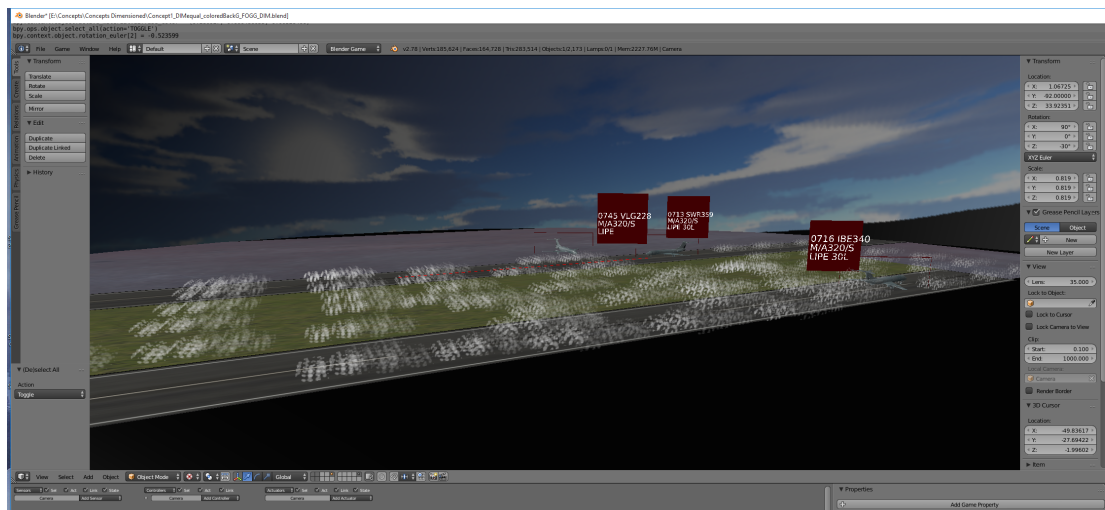

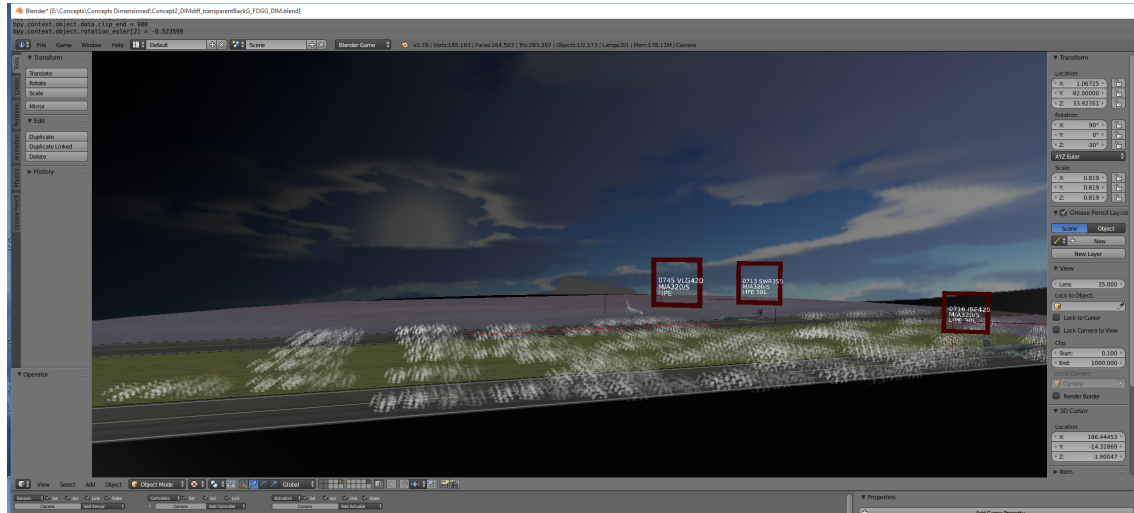*Figure 50. Top View of Foggy Scenario representation in Concept 1*

Figure 51. Top View of Foggy Scenario representation in Concept 2

The next image shows the vision of the ATCo from the control tower. Unlike the other scenarios (rain and sun effect) the aircrafts are not visible from the control tower because of the fog covers the surface. This is the softest situation that can be found in Bologna airport in a foggy day due to normally the humidity rounds between 80-95% and so on the fog covers the whole scenario not only the surface.
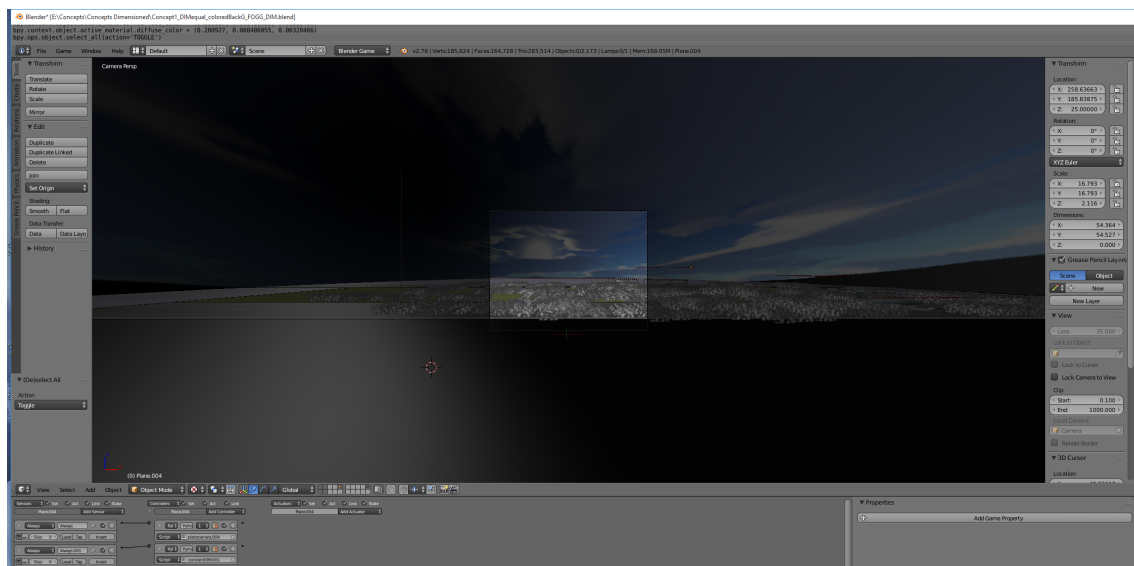

Figure 52. ATC view of Foggy Scenario

Concerning to the size and background factors, the conclusion is the same obtained on the rainy scenario representation. Because of:

✓ Coloured background is more visible that the transparent one, but it does not mean that the transparent one is not efficient or useful. So both can be apply.

✓ In relation with the size, the one remaining constant during all the representation (concept 1), is the one that has to be applied to achieve a good control over the aircrafts.
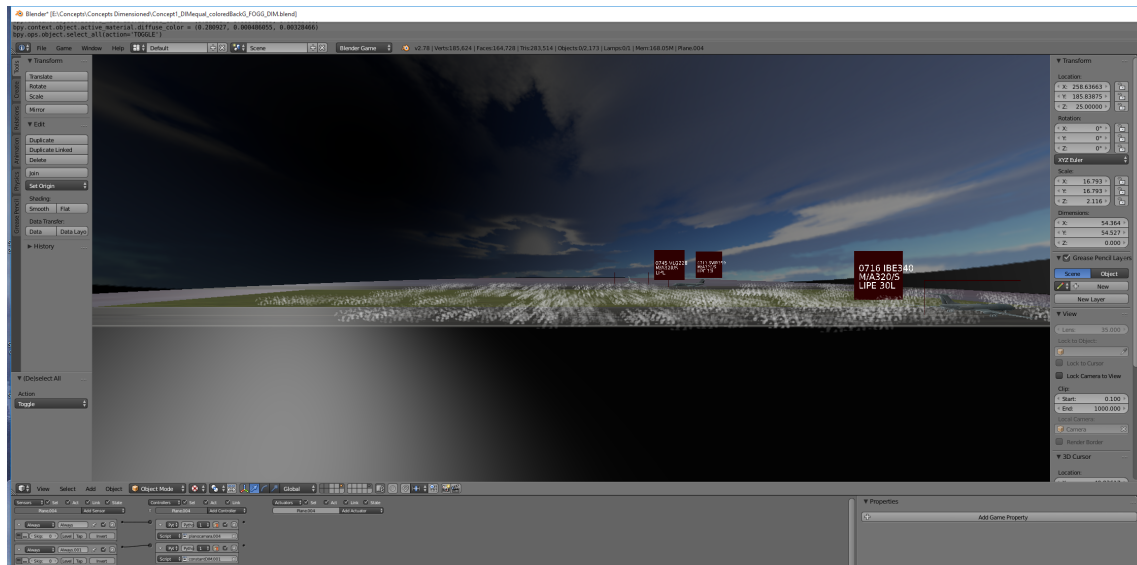

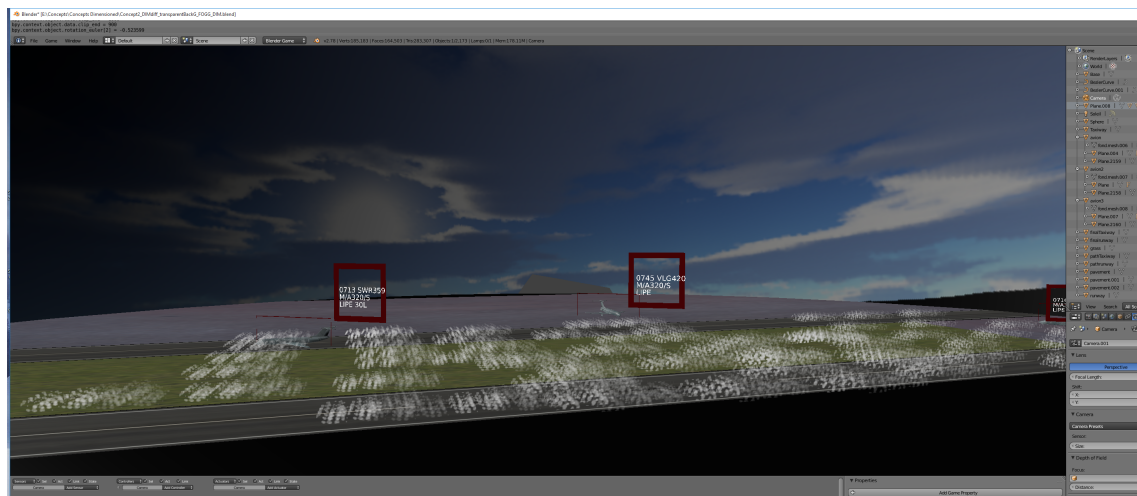*Figure 53. ATC view of Foggy Scenario representation in Concept 1*

Figure 54. ATC view of Foggy Scenario representation in Concept 2

The general conclusion obtained for an efficient and good aircraft control in the final scenario is:

✓ A constant dimensionless of the aircraft information to be readable by the ATCo from the control tower.
✓ Both backgrounds (coloured or transparent) can be applied depending on the climatological situation and the light it has. When the scenario has a low light intensity the transparent background is a good option, but when the scenario has a high light intensity the coloured background has to be applied, otherwise it will not be readable by the ATCo.

4.3. Description of the final scenario

This section is focused on defining the final scenario of Bologna Airport. In order to implement one of the scenarios described in section 4.2 with the corresponding factors that will provide a better visibility for the ATCo control.

At first the Bologna Airport scenario developed by Retina Project will be defined. The principal factors that form the scenario are the following:

- ✓ Control Tower
- ✓ Passengers Terminal
- ✓ The four parking areas.
- ✓ Runway, Taxiway and Exit Taxiways.

Figure 55. Aerial view of the Bologna Airport Scenario

Focusing in the Control Tower, as is the place from where the ATCo develops an accurate control of the aircrafts moving on the Airport, the important factor is the visibility that the controller has. So, the visibility that they have is shown in the next three figures (56, 57 and 58).
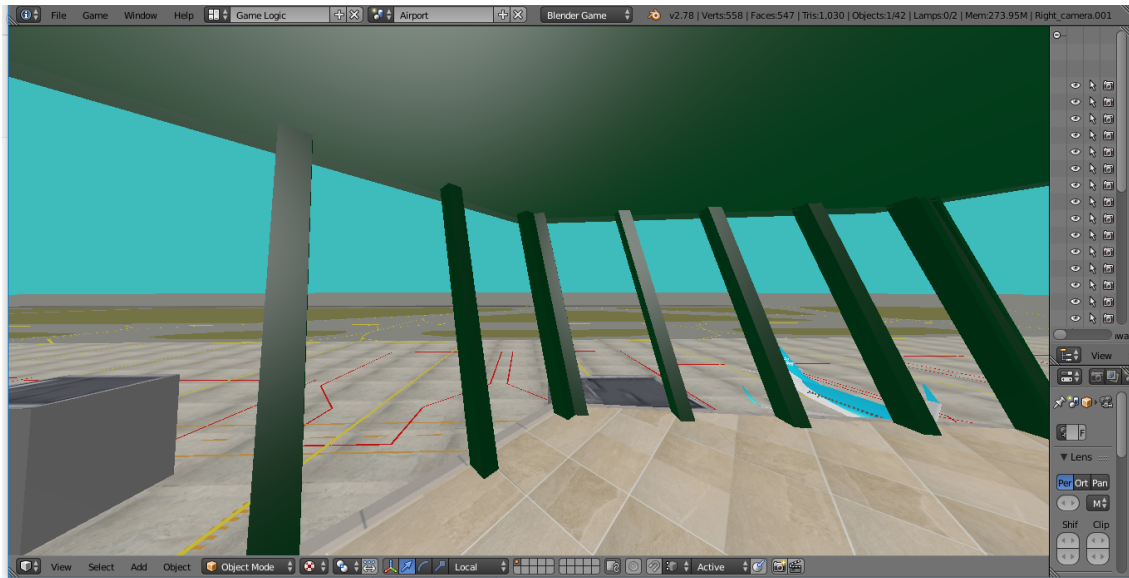
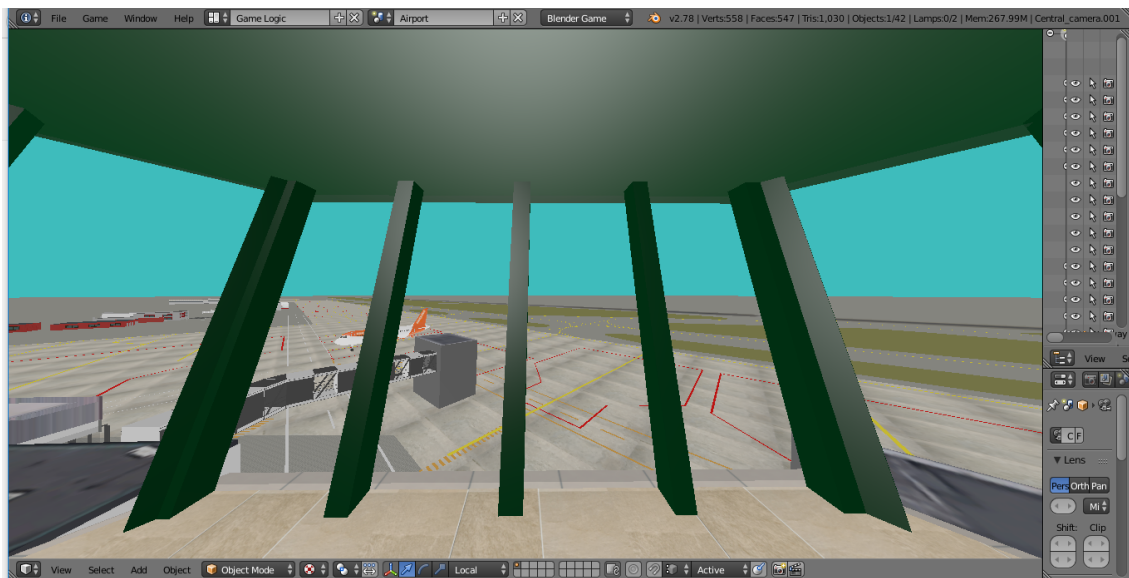*Figure 56. Right view of the ATC from the Control Tower*

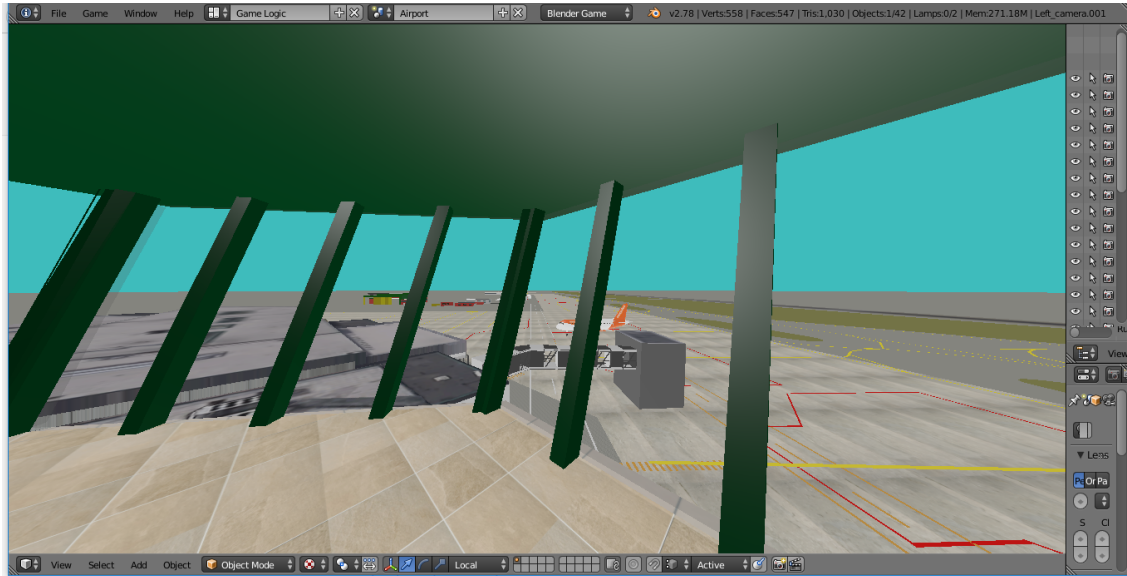*Figure 57. Central view of the ATC from the Control Tower*

Figure 58. Left view of the ATC from the Control Tower

Finally, it has to be applied the conclusions obtained in the last section 4.2 to provide a better visibility and an easy control of the aircrafts on the airport for the ATC. Likewise, it will be applied a constant dimension tool of the aircraft information to be readable by the ATC from the control tower and a coloured background to ensure that the flight information is readable regardless the light of the scenario and the climatological situation.

4.4. Final Scenario Representation in Blender

In this final section the final scenario is represented. At first it has been added two aircrafts running throw the Exit Taxiways, one approaching to the Control Tower and the other aircraft moving away.

As it is announced in the previous section 4.3 the Flight Progress strips attached to the aircrafts have a constant size regardless the position to be readable by the ATCo.

As the scenario represents a foggy climatological situation, the visibility of the ATCo is reduced. For this, the frame and the Flight Progress Strip background are coloured in red to be showier.
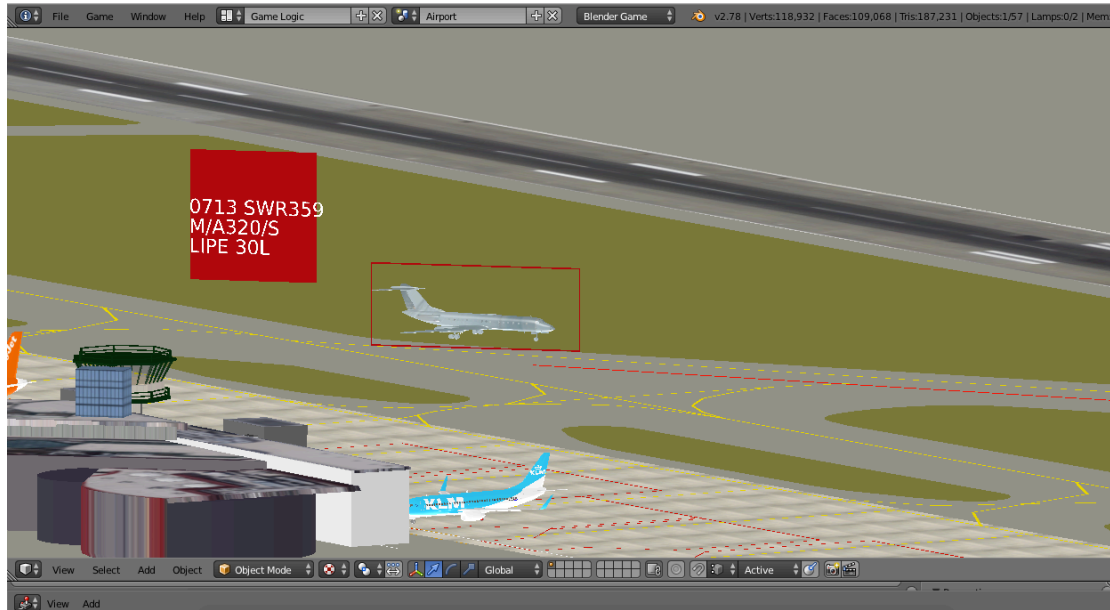
Figure 59. Aircraft running throw the Exit Taxiway

Figure 59 shows the movement of the aircraft throw the Exit Taxiway with the Flight Progress Strip and the frame facing the ATCo (the camera of the Control Tower).

In relation with the camera, in the Control Tower there are three diferent cameras. All of them are situated at the same position but with a diferent angle in Z-axis to cover a major region of the Bologna Airport. For this, the aircraft running throw the Exit Taxiway "F" moving away from the Control Tower, its frame and Flight Progress Strip faces with the central view of the ATCo, called in the program "Central_camera.001".
On the other hand, the aircraft running throw the Exit Taxiway "E" approaching to the Control Tower, its frame and Flight Progress Strip faces the left view of the ATCo, called in the program "Left_camera.001".

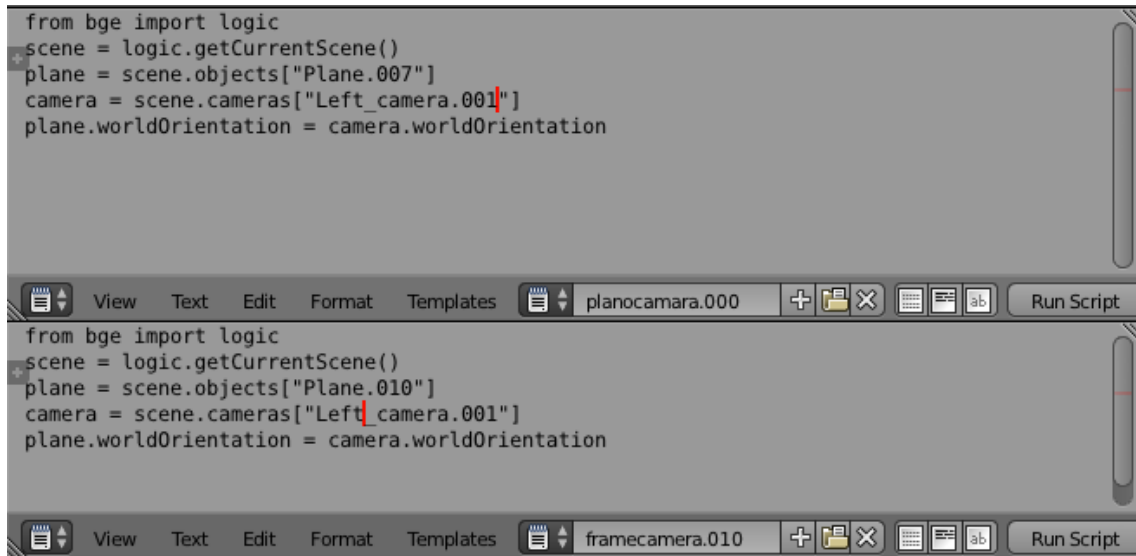Next Figures show the python code used in both cases.

```
from bge import logic
scene = logic.getCurrentScene()
plane = scene.objects["Plane.007"]
camera = scene.cameras["Left_camera.001"]
plane.worldOrientation = camera.worldOrientation
```

```
from bge import logic
scene = logic.getCurrentScene()
plane = scene.objects["Plane.010"]
camera = scene.cameras["Left_camera.001"]
plane.worldOrientation = camera.worldOrientation
```

Figure 60. Frame and plane facing left ATCo view

```
1 from bge import logic
2 scene = logic.getCurrentScene()
3 plane = scene.objects["Plane.002"]
4 camera = scene.cameras["Central_camera.001"]
5 plane.worldOrientation = camera.worldOrientation
```

```
from bge import logic
scene = logic.getCurrentScene()
plane = scene.objects["Plane.003"]
camera = scene.cameras["Central_camera.001"]
plane.worldOrientation = camera.worldOrientation
```
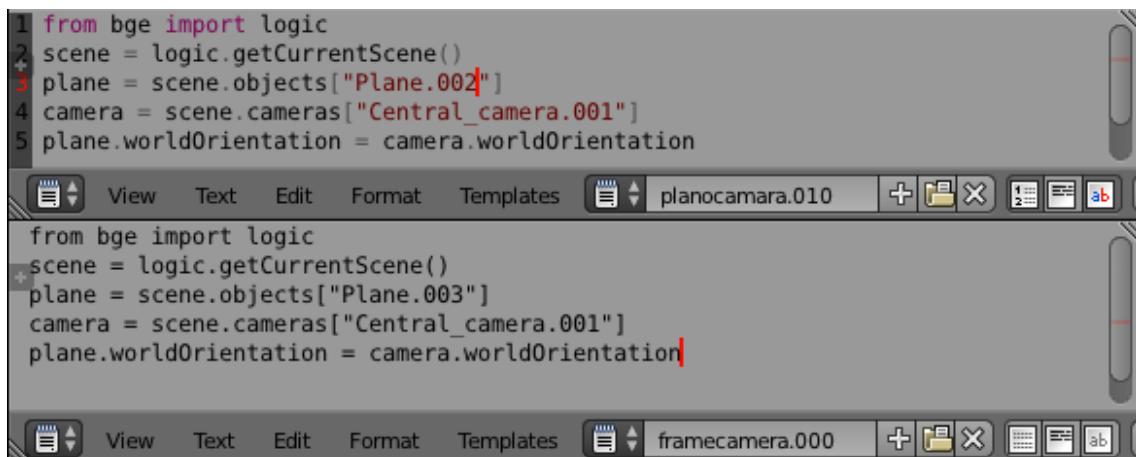
Figure 61. Frame and plane facing central ATCo view

The next step is to implement the foggy effect to the scenario, to do this it has been followed the same steps as in the section 4.2.3. Next two images show the final scenario with the all the actuators and with a poor visibility conditions due to the fog.
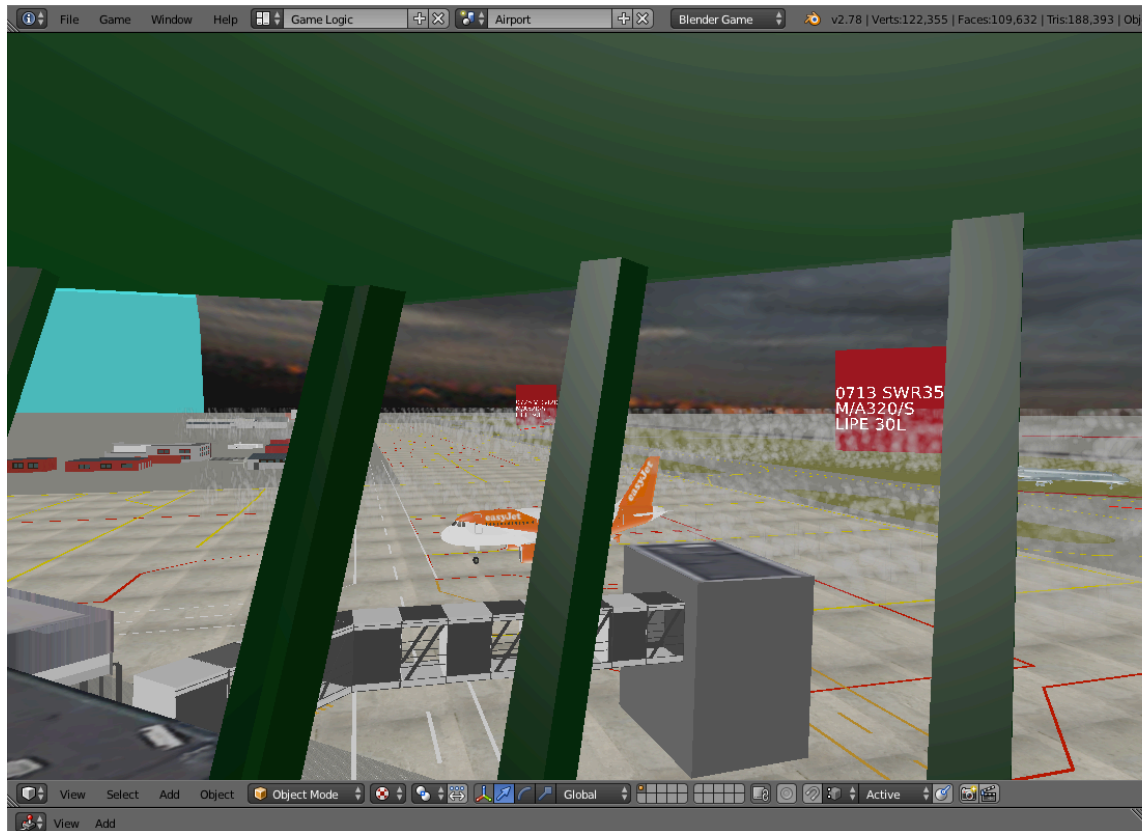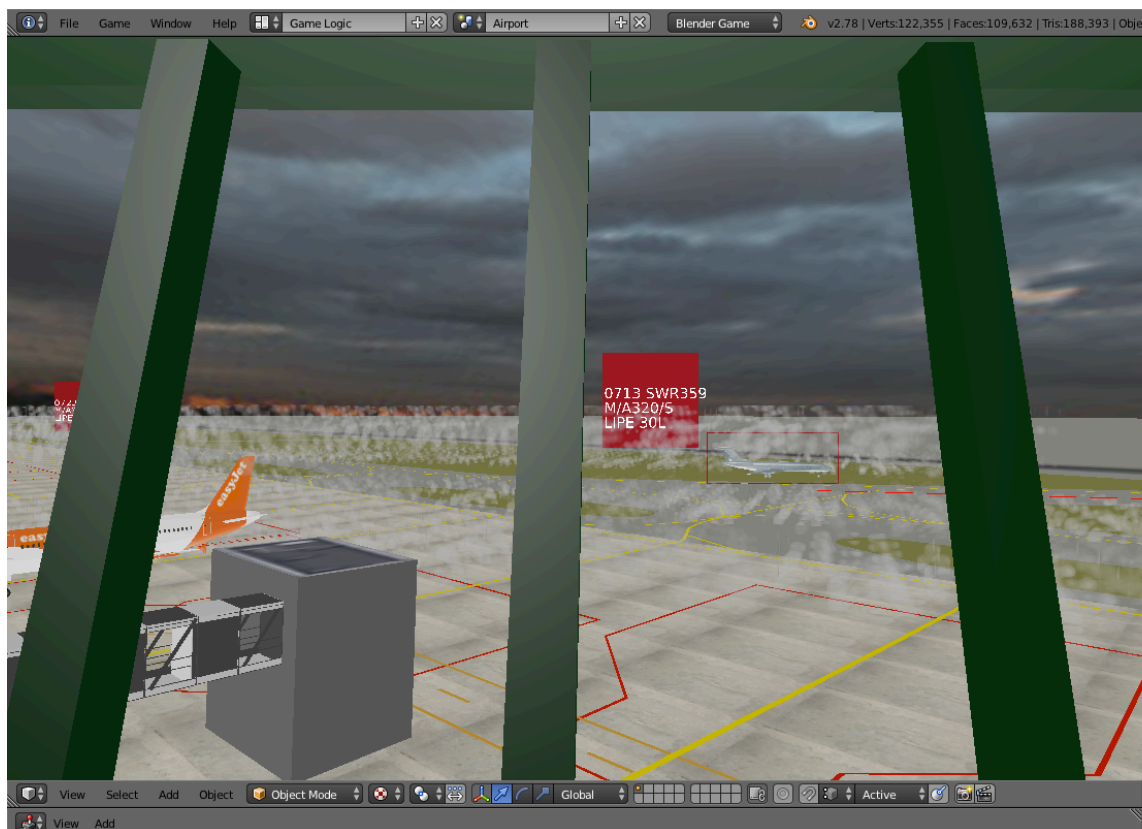
Figure 62. Left view of the ATCo.

Figure 63. Central view of the ATCo.

Conclusions

Hereafter this new experience in a Virtual Laboratory has provided the chance to work in 3D modelling with the Blender software. As working with a new software and at the same time getting in touch with a new script language called Python it had been possible to learn to get involved in this field.

At a first contact it was a little bit chaotic for working in a new and unknown field; but it was solve fully setting up an investigation by finding information about the matter. Thanks to the huge amount of information found it was easy to make progresses in the project on an independent way.

On the same way have worked with the two modes of the Blender Software, Render and Game Engine mode; deciding at the end which one is more useful for developing the project.
Therefore, Blender Game Engine mode was the one more useful and efficient because of:

- o All the past contributions to the Retina project were developed in this mode, so this part of the project must to be compatible with them.
- o The facility and the capacity that Game Engine mode brings to the user to work on real time simulation.

To sum up, to have had the possibility to take part in a project of this dimensions and with a clear and useful objective; pave the way into a new sector of big interest and with a large technological advances.

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Nicola Masotti, Sara Bagassi, Francesca De Crescenzio (Department of Industrial Engineering, University of Bologna)

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[6] https://es.wikipedia.org/wiki/Aeropuerto_de_Bolonia

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[9]   http://www.bologna-airport.it/en/corporate/business/aviation/runway-e-infrastructure.aspx?idC=61690&LN=en-US

[10] http://nats.aero/blog/2015/05/the-anatomy-of-a-flight-strip/

ANNEX

THESIS TITLE: Symbolic Representation of Scenarios in Bologna Airport on Virtual Reality Concept

DEGREE: Air Navigation Degree and Airport's Degree

AUTORS: Mercè Buyse Sanchez
Daniel Ramos Isidoro

DIRECTOR: Francesca De Crescenzio

DATE: January 2017

Symbolic Representation of scenarios in Bologna Airport on Virtual Reality Concept

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Chapter 1. Laboratory of Virtual Reality

1.1.   Retina Project

Starting with SESAR, that is a European program that works on the frame of developing the future Air Traffic Control System; I focused on RETINA Project that has been funded by it.

RETINA Project   (Resilient Synthetic Vision for Advanced Control Tower Air Navigation Service Provision) is part of the Horizon 2020 exploratory research projects of SESAR and has been funded under the Sesar-06-2015–High Performing Airport Operations topic.

The aim of this Project is investigate the potential and application of Synthetic Vision tools and Virtual and Augmented Reality display techniques for the Air Traffic Control service focused in the airport control tower. For this, the project will develop an interface taking into account all the requirements needed through specific design methods and tools. [1]

1.2.   Virtual Laboratory

The laboratory of Virtual Reality works on those sectors related with the investigation and the experimentation of techniques to promote its employment in aeronautical or aerospace applications, and also, in other sectors of industrial and social (environmental motorization and safety) importance.

For those, the tools and the competences offered in the laboratory bring to develop searches, prototypes and different applications in the different areas shown in figure 1:
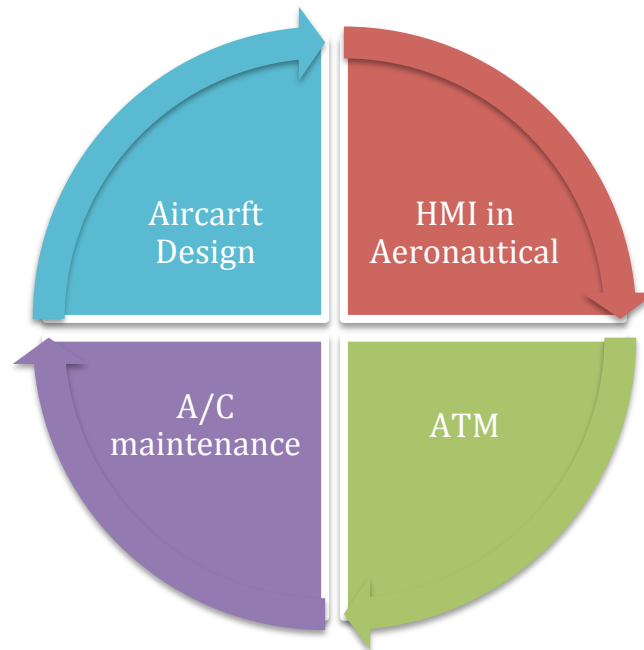
Figure 1. Different areas of Virtual Reality application

In which the Virtual reality/Augmented Reality applies on the maintenance, assemblage, human factors for planning, training and support to the product and the Systems of vision for unmanned vehicles works on UAV aircrafts planning mission and distance pilotage. [2]

1.2.1. What is carrying on in the Laboratory

A huge amount of advanced technologies are being developed in the laboratory to improve the realism and the usability on the virtual reality applications to achieve the integration in the processes and bring industrial support, understood faraway the integration with the system CAD.

On the other hand, the laboratory related with augmented reality sets systems able to combine the reality and the virtual one.

Working on the purpose of improving the situational awareness, includes to work on these factors:

- Remote Vision
- Glass Cockpit
- Augmented Vision
- Synthetic Vision

In these emergent sectors that are being applied by developing algorithms and systems; working on the design of different prototypes and the test of them. The main tools working on are:

- Multisensor-Multitemporal data fusion
- Target identification and tracking
- 3D modelling

1.2.2. Instrumentation

- System of stereoscopic projection
- Devices of interface for Virtual Reality
- Software of Virtual Reality

1.3. Participation

My contribution to the RETINA project, focuses on the symbolic representation of additional data and parameters to be overlayed as aircraft information.

ATC nowadays is being conditioned by some factors as the huge amount of workload, meteorological adverse factors, poor visibility and different kind of situational awareness that they must confront.

Therefore, this project uses the virtual reality to offer a possible solution; by reproducing different scenarios (meteorological ones and distances between controller and aircraft) that contain those unfavorable factors for the controller and the aircraft and test distinct prototypes to get, at the end, the most efficient solution.

Chapter 2. Blender Software

Blender is a software of 3D creation. It supports the entire 3D modeling, animation, simulation, rendering, compositing and motion tracking of a video or game creation. The library of Blender's API for Python scripting, is used to create and apply advanced specialized tools; most of tools are already implemented in Blender's software, but all the objects and meshes can be animated by programming an specific code in python language.

2.1. Blender Render and Blender Game Engine

Blender software is divided into different modes, as Render Engine, Game Engine and Cycles Engine. For the project the ones that have been important and developed are Render and Game Engine modes.

Although the two modes have been learned and used for developing the task, a large amount of differences exist between the two modes.

Blender Render is used to create a 2D image from a scene on 3D. [3]

It must be taken into account that the scene is modeled by the user and different factors can be added or modified as:

- o   Camera
- o   Illumination in the scene
- o   Material and texture of each object
- o   Various render settings (quality, size, layers, colours…)

Depending on the complexity of the scene it can take more or less time to work out some complex calculations based on those factors to obtain a render image.

On the other hand, the Blender Game Engine (BGE) is a tool for real time projects, from architectural visualizations and simulations to games. For this mode it's useful to animate the object by python code to achieve a real animation. [4]

Chapter 3. Project development in Blender

Initially I focused in learning the basic functions of the software Blender Render. From basic tutorials, I have learned how to interact, animate, action and model a basic element.

Although the software has multiples modes, I have worked with the two ones, Blender Render and Game Engine, more useful for the purpose as well as the main functions required.

In the same way the application of Python code has been required in some of the steps, for those I had to deal with a new language code. [5]

3.1. Steps followed

The task that is going to perform consists in building a 3D scene with an aircraft with a 3D tag that is registered with the aircraft and that contains the Flight information.

The observer of the scene (ATC), represented by a virtual camera, has to gather the information in the flight tag at any time the aircraft is visible by its point of view.

a. Download the aircraft

The first step has been downloading the aircraft in (.blend) to be compatible with the software.
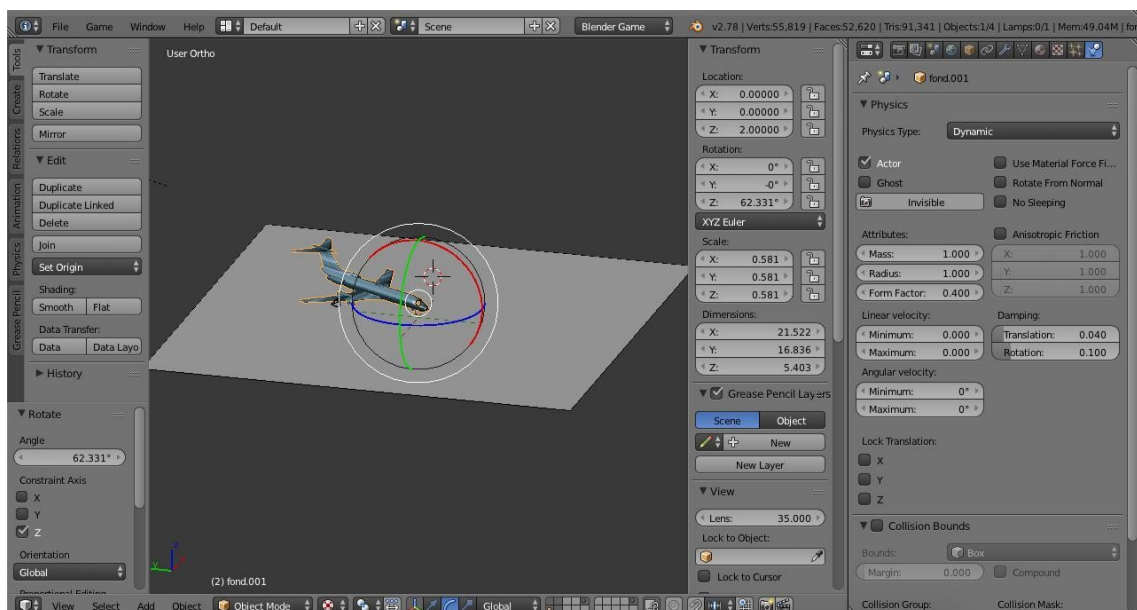

Figure 2. Prototype of aircraft used

b. Parenting the plane and text to the aircraft

In order to connect two objects in Blender, it must be chosen one object as the father and one object as the son; by this way the son will do exactly every single step that the father does. In both modes (Render and Game Engine) the function used is "parent to" ("CNTRL +P").

c. Programming text/plane facing the camera

In Blender render is apply the constrain "Track to" and choosing the camera as a target to the object that must face the camera. [6]
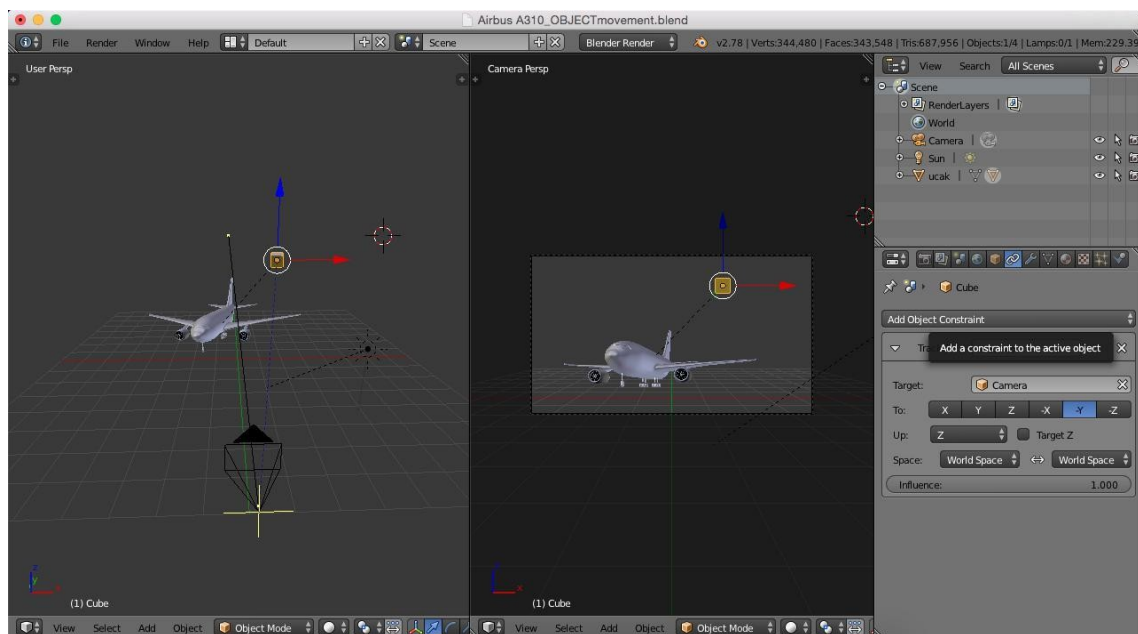

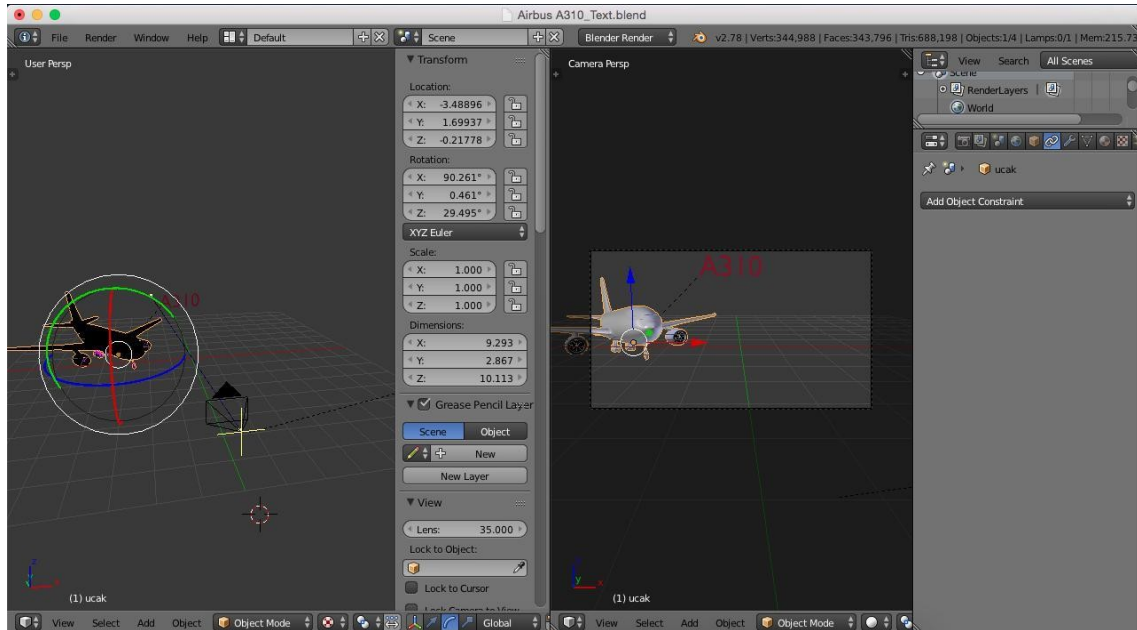**Figure 3. Plane parent with the aircraft facing the camera**

Figure 4. Text parent with the aircraft facing the camera

In Blende Engine is applied a Python code. Working with the Logic editor is added an "always" sensor and a "Python" controller to the text or object that must face to the camera.
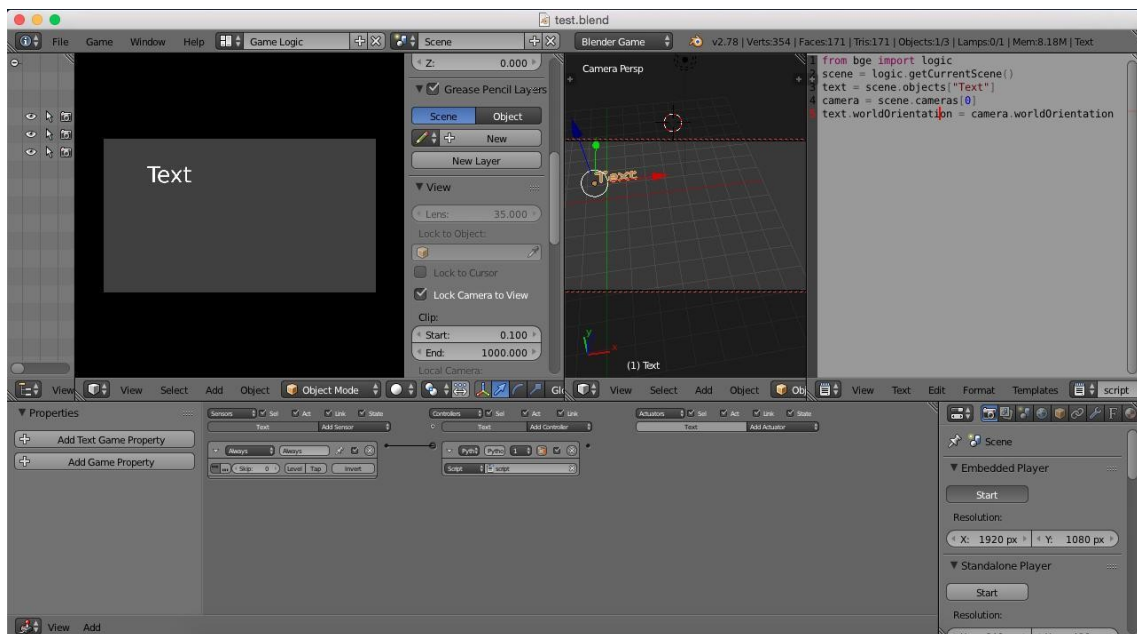

Figure 5. Text facing the camera using Python code

Python code to face the text to the camera	Python code to face plane to the camera
from bge import logic	*from bge import logic scene*
logic.getCurrentScene()	*scene = logic.getCurrentScene()*
text = scene.objects["Text"]	*plane = scene.objects["Plane"]*
camera = scene.cameras[0]	*camera = scene.cameras[0]*
text.worldOrientation =	*plane.worldOrientation =*
camera.worldOrientation	*camera.worldOrientation*

d. Designing a path which the aircraft follows

It has been necessary to design a path for simulating the "real" movement of an aircraft. Therefore, it has been followed the next procedure to perform the path in both modes.

Render mode

At first it's created a "NurbsPath" which can be modelled as own wish. Then the aircraft and the "NurbsPath" are parented selecting the option "Path following". Finally, to be more realistic, on the timeline selecting each frame can be given a specific orientation, position and rotation for the aircraft.
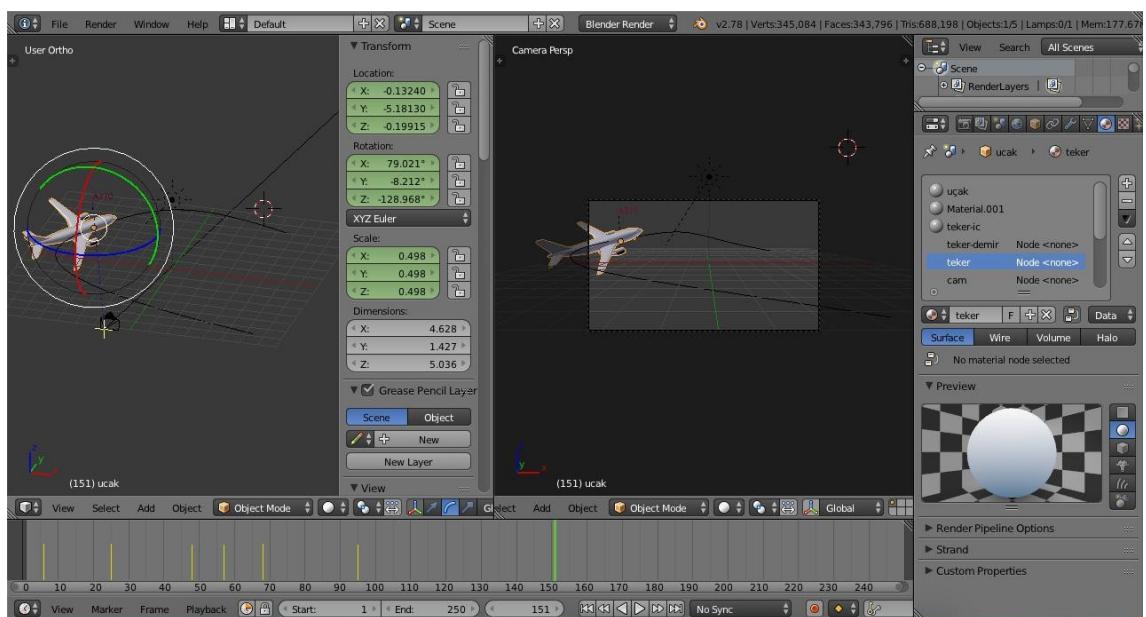

Figure 6. Path computed in Blender Render mode

Game Engine mode

To create a path in game engine several functions and constraint must to be applied. At first should be created a "BezierCurve" where can be modelled as it is desired. Then a plane is created parallel and above the "BezierCurve". Two constraints must be applied to the plane, "Array" and "Curve", while selecting the "BeizerCurve". The path obtained must be indicated as a "Navigation Mesh" to be followed by the aircraft.

Finally, in the Logic Editor, an "Always" sensor, a "And" controller and a "Steering" actuator with a behaviour of "Path following" must be created.
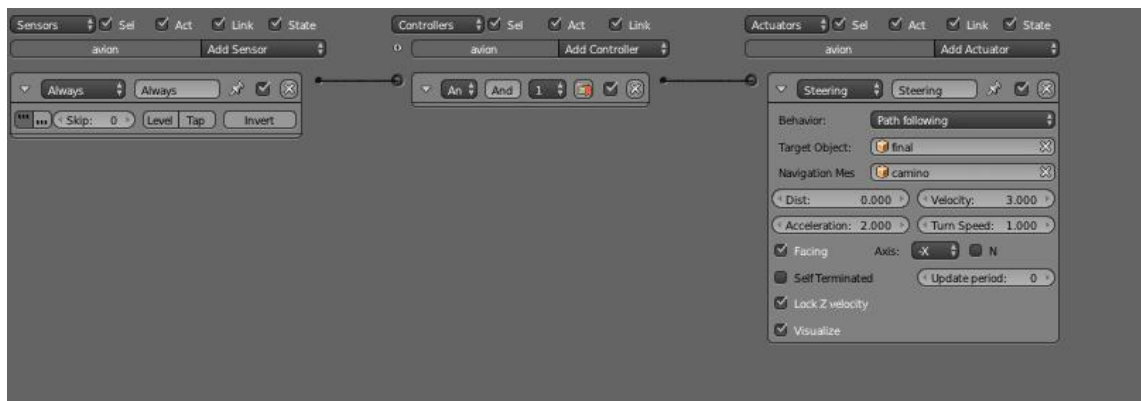

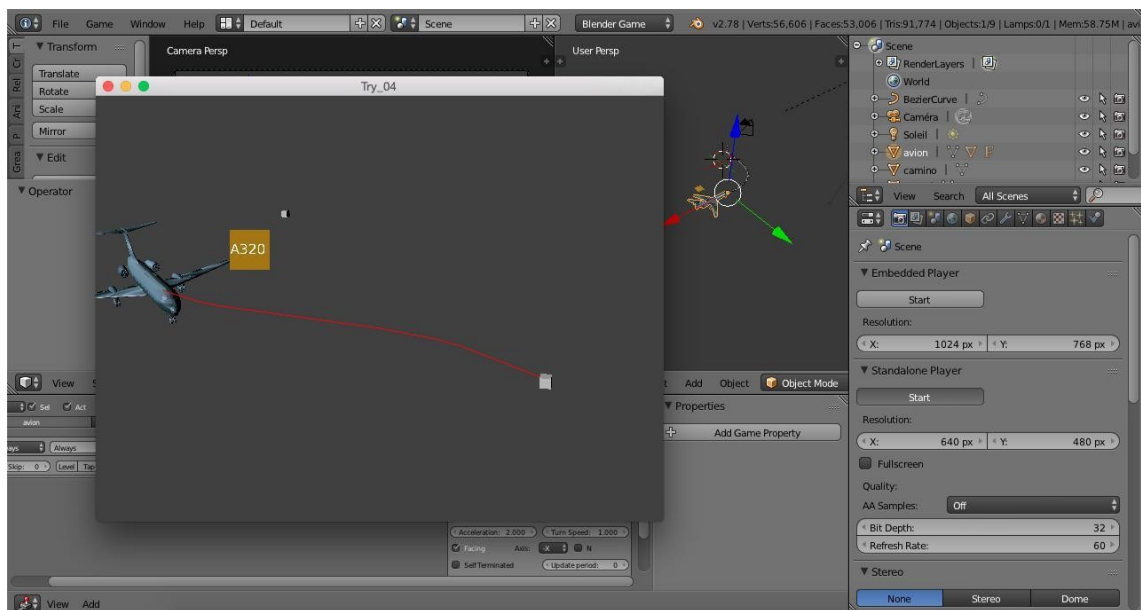Figure 7. Sensor, Controller and Actuator used in Logic Editor

Figure 8. Path computed in Blender Game Engine mode

3.2. Improvement of the prototype

Once the basic prototype is done, it is need to focus on possible improvements of it to facilitate the work of the controller. For this reason, and taking into account the possible needs of the ATC, it has been developed by Python a way of maintaining constant the size of the plane that contains the text (information of the aircraft) instead of having the size of the text changing according to position of the aircraft (distance to the control tower constantly changes).

The way of obtaining it is using the Python code shown in the table above to a "Python" controller in the Logic editor and also linking it to an "Always" sensor. [7]
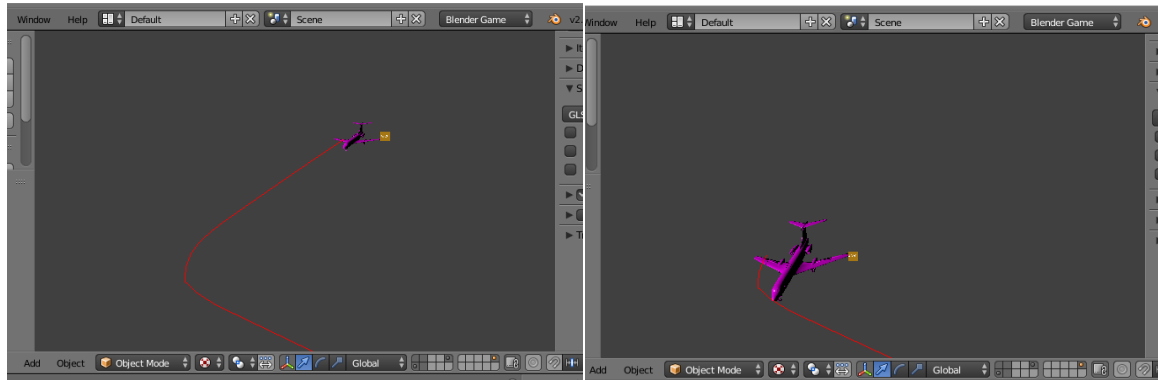

Figure 9. Information of the aircraft with the same size regardless the position

The image above shows the text with the information of the aircraft with the same size all the time regardless of the distance; and the image below shows the same aircraft in the same position but the text changes accordingly with the distance.
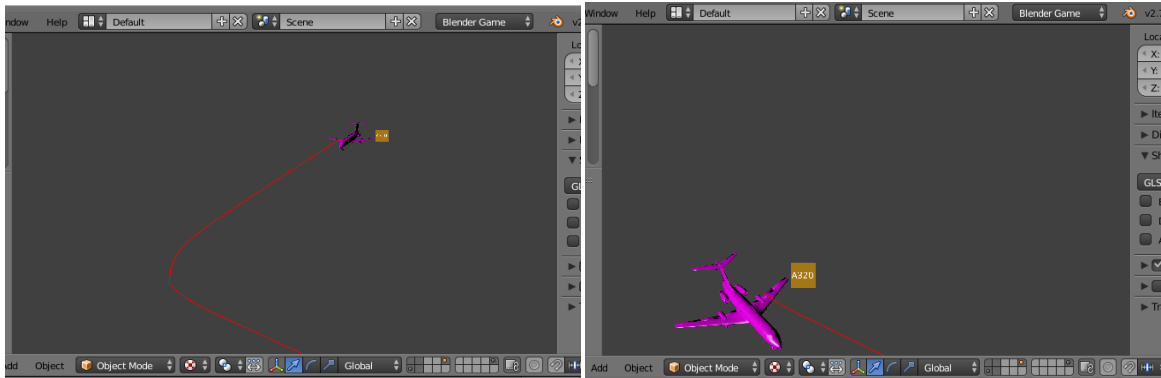

Figure 10. Information of the aircraft with different size according to the position

Python code that remains the text with the same size regardless the distance
import bge *owner = bge.logic.getCurrentController().owner* *camera = owner.scene.active_camera* *distance = owner.getDistanceTo(camera)* *try:* *originalDistance = owner["originalDistance"]* *originalScale = owner["scale"]* *owner.localScale = originalScale * distance/originalDistance* *except KeyError:* *owner["scale"] =* *owner.localScale.copy()* *owner["originalDistance"] =* *distance*

To sum up it have been implemented as an improvement, a frame that emphasize the aircrafts that must be controlled by the ATC. The objective was to achieve a similar image as it is shown below.

Figure 11. Initial concept of a frame

To develop it in Blender Game Engine, at first it was created the frame; being a plane drilled by a cube of a specified dimensions and using the "Boolean" constraint, selecting the cube as a target and remaining with the difference of the surface. Secondly, a "Parent" constraint have been applied between the frame and the aircraft to reach the exactly movement on the frame as the aircraft.

Finally, to face the frame to the camera, the same Python code used previously to face a plane to the camera has been applied.

The final result obtained is shown in the next image:

Figure 12. Frame of the aircraft in Blender Game Engine

Chapter 4. Conclusions

Hereafter this new experience in a Virtual Laboratory has been provided to me the chance to work in 3D modelling with the Blender software. As working with a new software and at the same time getting in touch with a new script language called Python I have learned to get involved in this field.

At a first contact it was a little bit chaotic for me working in a new and unknown field; but it was solve fully setting up an investigation by finding information about the matter. Thanks to the huge amount of information found it was easy to make progresses in the project on an independent way.

On the same way I have worked with the two modes of the Blender Software, Render and Game Engine mode; deciding at the end which one is more useful for developing the project.
Therefore, Blender Game Engine mode was the one more useful and efficient because of:

- o All the past contributions to the Retina project were developed in this mode, so my part of the project must to be compatible with them.
- o The facility and the capacity that Game Engine mode brings to the user to work on real time simulation.

To sum up, to have had the possibility to take part in a project of this dimensions and with a clear and useful objective; pave the way to me into a new sector of big interest and with a large technological advances.

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