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MAP SERVER FOR VISUALIZING AIR TRAFFIC BASED ON DATA FROM A REMOTE PSEUDO RADAR

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Abstract

In order to ensure the safety of aircraft operating in airspace, air traffic controllers apply a number of rules recommended by the ICAO, known as "separation rules". Previously using essentially the calculation of the estimates, they are based today on the visualization of the traffic through Air Traffic Management Systems. Traffic data comes from several sources. These include radar data from Air Traffic Control Radars. The objective of this work is to simulate, using a web map server, the evolution of air traffic: positions and flight levels of aircraft over time based on radar data. For this we use three parts. The first part, the pseudo radar, is a remote radar data server that, depending on the time, sends the data to the map server that is the second part. The *latter receives this data and combines it with other geographical and cartographic data and sends them in turn to the client via the web server. The client, a simple interface finally displays the positions of aircraft on screen.*

Keywords

Air Traffic Control, Air Traffic Control Radar, Air Traffic Management Systems, Geographical Information System, Web Map Server

1. Introduction

Safety in the field of air transport has always been a key element in civil aviation. Early on, ICAO started to set the rules governing air traffic. These are intended to preserve the safety of aircraft, but also to allow a better flow of traffic in constant increase.

In practice, airspace management is the responsibility of regional bodies (such as Eurocontrol for Europe) or national (such as ENNA for Algeria). Airspace is divided into sectors based on functional criteria and services rendered. It is the responsibility of the air traffic controller to best manage the air traffic in his sector (Doc4444, 2016).

Initially, air traffic controller worked on the procedures (the exchange of information between controller and pilot is limited to radio) (Doc4444, 2016). With the evolution of information technologies, the use of Air Traffic Management Systems (ATMS) is now widespread (Doc9750, 2016). It is no longer necessary to "imagine" the configuration of the traffic at a given moment; it is enough to visualize the traffic on a HMI and to exploit the displayed data to take the necessary decisions.

To locate aircraft, Air ATMS rely on a multitude of data sources (ANNEX 10 VOL III, 2016), among them the radar of air navigation and it is on this one that our work is articulated.

The objective of this work is to simulate the evolution of air traffic: positions and flight levels of aircraft over time based on this kind of data by using a very simple computer tools such as geographic servers and web browsers on PC or smartphone (Mohamad, 2016). The idea is to allow, later and at a lower cost, access to air traffic data if the source of these data is real.

For this, the proposed architecture is in three entities. The first entity called pseudo-radar, a remote radar data server, whose role is to generate the radar data. It sends, as a function of time, the data to a second entity, a map server. The latter receives this data and combines it with other geographical and cartographic data to send them in turn, via the web server, to the third entity called client. Finally, the client, which is nothing other than a simple interface, displays the positions of the aircraft on the screen.

To better situate our work, it is useful to focus on certain aspects. In the next section, we will discuss works related to air traffic simulation. Then, we will fly over Air Traffic Control Radar as well as the contents of the information which it generates. Our work is based on geographic information and Web solution; we will also approach geographic information systems and web mapping. In the third section, we will discuss the details of the design and the results obtained. Finally, we will conclude with a conclusion and perspectives.

2. Related Works

Our goal is to simulate, in a web browser, air traffic from pseudo-remote radar. In order to situate our work and the solutions proposing simulators of traffic or air control being quite numerous, we limit ourselves to fly over some of these solutions.

Several research projects have been carried out in this direction. (Brown and Slater, 1997) studied the experiences of designing and using 3D screens. (Glover and Lygeros, 2004) proposed an agent-based traffic generation model for simulation, conflict detection and resolution. (Grether & al., 2013) used also an agent-based model for the traffic forecast. (Karaman, 2018) relied on the Monte Carlo method to solve the problem of traffic congestion.

If we are interested in the architecture of the proposed simulation solutions, we find essentially two types of solutions: desktop and web architectures.

Regarding desktop applications, we can mention AMELIA (Hauksdóttir & al., 1998), developed by the University of Iceland and which has several fields of application (for the training of air traffic controllers or as a test tool for radar data processing systems). There is also Eurocontrol Project AMANDA or the ATOMS project (Alam & al., 2008) that are based on multi-agent systems and require installation.

In respect of Web applications, we can mention NARSIM (NARCIM, 2019) a real-time solution and usable for research. It has the advantage of being configurable but is not free. In (AirPortOnline, 2019) and ATMOS (ATMOS, 2019), simulation remains limited to aerodromes and take-off and approach phases while (ATCSIM, 2015) allows to choose the simulation and to interact with the aircraft without allowing to load the radar data.

The solution we propose here is part of the web-oriented architecture.

3. ATMS and Air Traffic Control Radar

Air Traffic Management (ATM) is defined in (Doc9854, 2005) as "the dynamic, integrated management of air traffic and airspace — safely, economically and efficiently — through the provision of facilities and seamless services in collaboration with all parties".

ATMS are fed with traffic data by air navigation radars mainly covering the airspace controlled by the air traffic control services.

Air Traffic Control Radar (ATC Radar) follows the same principle as the conventional radar (Rahman, 2019). ATC Radar sends pulses of energy (transmitter) while rotating on a vertical axis and receives the echo of these impulses through a receiver. By measuring the time required for any return to the antenna and having the direction of the antenna at the time of reception, the radar system can determine the distance ρ and direction θ of the aircraft (see Figure 1).

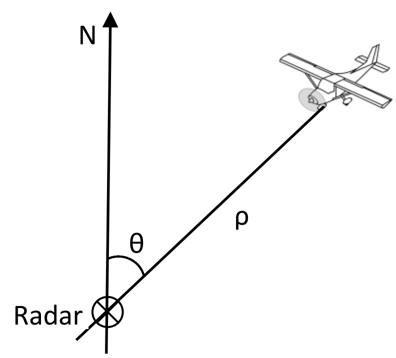


Figure 1: *Positioning of the Aircraft in Relation to the ATC Radar*

There are two kinds of ATC Radar: Primary Surveillance Radar (PSR) and

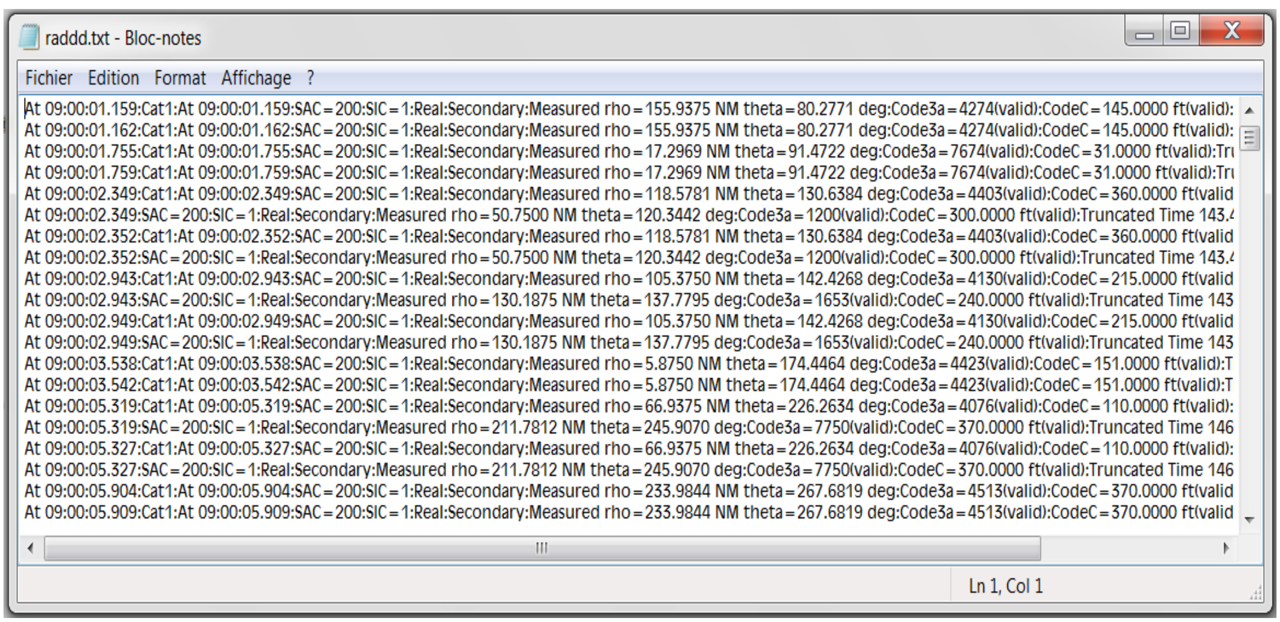
Secondary Surveillance Radar (SSR). This one differs from the PSR by the fact that it is equipped with transponders to transmit data to the radar system such as the flight level. In our case, we use SSR data.

There are several formats for radar data. The best known is the ASTERIX (*All Purpose Structured Eurocontrol Surveillance Information EXchange*) format, which is a standardized format and is used at European level by EUROCONTROL (Eurocontrol, 2016).

ASTERIX messages are transmitted in binary form by the radar station. They are decomposed into blocks themselves structured in fields. Table 1 describes the main content of these messages as well as examples of values extracted from an ASTERIX format radar data file transformed displayed in clear text (see Figure 2).

Table 1: *Main Items Contained in a Message in ASTERIX Format*

Items	Description	Example
Time	Time of capture of the position of the aircraft	*At 09:00:01.159*
SAC/SIC	Unique identifier of the radar system - SAC (Source Area Code): eight-bit number assigned to a country or a territory. - SIC (System Identification Code): eight-bit number assigned to each radar station (located in the country or territory as defined by the SAC) from which data are received.	SAC=200:SIC=1 (Country: Algeria, Radar Station : Oued Smar)
Position	Represented with two parameters: *rho (ρ)* and *theta (θ)*. - *Rho (ρ)* is the distance (expressed in nautical miles) between the aircraft and the Secondary Surveillance Radar (SSR), - *theta (θ)* is the angle (expressed in degrees) formed by three points: Magnetic North, radar position, and aircraft position.	rho=155.9375 NM theta=80.2771 deg
Code3a	Called also SSR code, it plays the role of the identifier of plane. Each aircraft has a unique code3a that distinguishes it from other aircraft detected by the radar. The assignment of the SSR code is regulated according to ICAO recommendations (Doc 9684, 2004)	Code3a=4274
CodeC	It corresponds to the flight level (FL) which represents the height of the aircraft expressed in feet (ft)	CodeC=145.0000 ft


raddd.txt - Bloc-notes
Fichier Edition Format Affichage ?
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At 09:00:01.159:Cat1:At 09:00:01.159:SAC=200:SIC=1:Real:Secondary:Measured rho=155.9375 NM theta=80.2771 deg:Code3a=4274(valid):CodeC=145.0000 ft(valid):
At 09:00:01.162:Cat1:At 09:00:01.162:SAC=200:SIC=1:Real:Secondary:Measured rho=155.9375 NM theta=80.2771 deg:Code3a=4274(valid):CodeC=145.0000 ft(valid):
At 09:00:01.755:Cat1:At 09:00:01.755:SAC=200:SIC=1:Real:Secondary:Measured rho=17.2969 NM theta=91.4722 deg:Code3a=7674(valid):CodeC=31.0000 ft(valid):Tru
At 09:00:01.759:Cat1:At 09:00:01.759:SAC=200:SIC=1:Real:Secondary:Measured rho=17.2969 NM theta=91.4722 deg:Code3a=7674(valid):CodeC=31.0000 ft(valid):Tru
At 09:00:02.349:Cat1:At 09:00:02.349:SAC=200:SIC=1:Real:Secondary:Measured rho=118.5781 NM theta=130.6384 deg:Code3a=4403(valid):CodeC=360.0000 ft(valid
At 09:00:02.349:SAC=200:SIC=1:Real:Secondary:Measured rho=50.7500 NM theta=120.3442 deg:Code3a=1200(valid):CodeC=300.0000 ft(valid):Truncated Time 143.
At 09:00:02.352:Cat1:At 09:00:02.352:SAC=200:SIC=1:Real:Secondary:Measured rho=118.5781 NM theta=130.6384 deg:Code3a=4403(valid):CodeC=360.0000 ft(valid
At 09:00:02.352:SAC=200:SIC=1:Real:Secondary:Measured rho=50.7500 NM theta=120.3442 deg:Code3a=1200(valid):CodeC=300.0000 ft(valid):Truncated Time 143.
At 09:00:02.943:Cat1:At 09:00:02.943:SAC=200:SIC=1:Real:Secondary:Measured rho=105.3750 NM theta=142.4268 deg:Code3a=4130(valid):CodeC=215.0000 ft(valid
At 09:00:02.943:SAC=200:SIC=1:Real:Secondary:Measured rho=130.1875 NM theta=137.7795 deg:Code3a=1653(valid):CodeC=240.0000 ft(valid):Truncated Time 143
At 09:00:02.949:Cat1:At 09:00:02.949:SAC=200:SIC=1:Real:Secondary:Measured rho=105.3750 NM theta=142.4268 deg:Code3a=4130(valid):CodeC=215.0000 ft(valid
At 09:00:02.949:SAC=200:SIC=1:Real:Secondary:Measured rho=130.1875 NM theta=137.7795 deg:Code3a=1653(valid):CodeC=240.0000 ft(valid):Truncated Time 143
At 09:00:03.538:Cat1:At 09:00:03.538:SAC=200:SIC=1:Real:Secondary:Measured rho=5.8750 NM theta=174.4464 deg:Code3a=4423(valid):CodeC=151.0000 ft(valid):T
At 09:00:03.542:Cat1:At 09:00:03.542:SAC=200:SIC=1:Real:Secondary:Measured rho=5.8750 NM theta=174.4464 deg:Code3a=4423(valid):CodeC=151.0000 ft(valid):T
At 09:00:05.319:Cat1:At 09:00:05.319:SAC=200:SIC=1:Real:Secondary:Measured rho=66.9375 NM theta=226.2634 deg:Code3a=4076(valid):CodeC=110.0000 ft(valid):
At 09:00:05.319:SAC=200:SIC=1:Real:Secondary:Measured rho=211.7812 NM theta=245.9070 deg:Code3a=7750(valid):CodeC=370.0000 ft(valid):Truncated Time 146
At 09:00:05.327:Cat1:At 09:00:05.327:SAC=200:SIC=1:Real:Secondary:Measured rho=66.9375 NM theta=226.2634 deg:Code3a=4076(valid):CodeC=110.0000 ft(valid):
At 09:00:05.327:SAC=200:SIC=1:Real:Secondary:Measured rho=211.7812 NM theta=245.9070 deg:Code3a=7750(valid):CodeC=370.0000 ft(valid):Truncated Time 146
At 09:00:05.904:Cat1:At 09:00:05.904:SAC=200:SIC=1:Real:Secondary:Measured rho=233.9844 NM theta=267.6819 deg:Code3a=4513(valid):CodeC=370.0000 ft(valid
At 09:00:05.909:Cat1:At 09:00:05.909:SAC=200:SIC=1:Real:Secondary:Measured rho=233.9844 NM theta=267.6819 deg:Code3a=4513(valid):CodeC=370.0000 ft(valid
```
Ln 1, Col 1

Figure 2: *Sample Radar Data in ASTERIX Format saved in a File and Displayed in Clear Text*

4. Geographical Information System and Web Mapping

As we said in the related works section, the work we propose is in web architecture. Given the nature of the data manipulated, we are also in the perspective of Geographic Information Systems (GIS). The combination of the two gives what is called, with some differences, web mapping or web GIS.

(Huisman, 2009) defined GIS as: *"a computer-based system that provides the following four sets of capabilities to handle georeferenced data:*

- *Data capture and preparation*
- *Data management, including storage and maintenance*
- *Data manipulation and analysis*
- *Data presentation"*

Whereas (Neumann, 2008) defined web mapping as "the process of designing, implementing, generating and delivering maps on the World Wide Web".

The application we have developed responds precisely to this definition. As we will see later, the result of the treatments will be accessible remotely via the web.

5. Proposed Solution

As mentioned in the introduction, our work essentially manipulates radar data that is geographical in nature. Moreover, since this radar data is sent by a pseudo-radar, the web solution we have chosen seems appropriate.

5.1 Proposed Architecture

Our proposed solution and its infrastructure are represented by the following schema (see Figure 3).

Initially, the client sends a request to the Web server which results in triggering the simulation. The web server receives it, interprets it and sends its arguments to the application server. In our case, the application server is a map server like MapServer. Indeed, it retrieves the data in its various forms, generates the WMS flow and sends it to the Web server to transmit it to the client via the http protocol.

In parallel, the pseudo-radar (radar data server) starts sending the traffic data to the ETL. This operation is performed asynchronously and according to the time information contained in the text file of the radar data set. The communication between the pseudo-radar and the ETL is via

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Java applets. The extracted raw data passes through the ETL tool which has the role of extracting them, transforming them, cleaning them and finally loading them into the PostgreSQL DBMS with its PostGIS geographical cartridge.

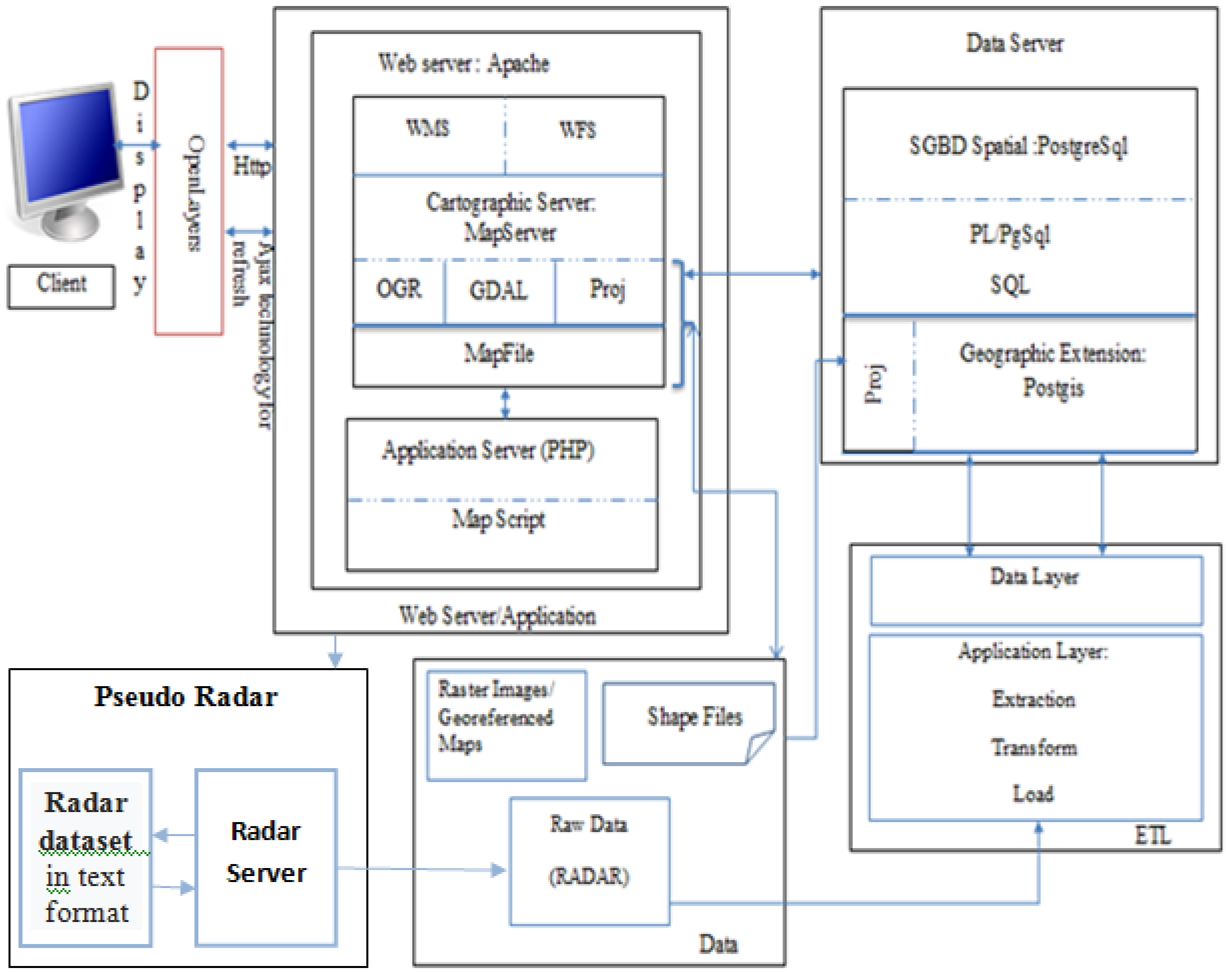


Figure 3: *Architecture of the Proposed Solution*

However, the transmission of the results involves the reloading of the entire web page: the interface, its functionalities, as well as all the data layers, which induces a relatively long response time. To overcome this problem, we use AJAX technology (asynchronous JavaScript and XML). It then changes the content of the web page displayed by the browser based on the results sent by the server, thus avoiding the transmission and display of the complete page. In this technology, data exchanges between the client and the server primarily use XML, but other formats can be used, such as JavaScript Object Notation (JSON), a data format inspired by the syntax of the JavaScript language. It is used to structure the information sent by the web server.

GeoJSON (Geographic JSON) exists for the manipulation of geographical objects. It is a variant of JSON that supports geographic data (point, line, and polygon). Thus, all the sections constituting the solution are encoded in GeoJSON and without going through the card server, they are sent to the application server for a new projection, then to the web server to be transmitted to the client. OpenLayers is a client-level JavaScript application that can handle GeoJSON. At this level, a line vector layer is created and sections are displayed.

4.2 Tools

For the solution we propose, we used the following tools:

4.2.1 DBMS:

We used PostgreSQL (v.10) with PostGIS (v.2.4) which provides spatial objects for the PostgreSQL database, allowing storage and query of information about location and mapping.

4.2.2 Mapserver:

Mapserver is an Open Source platform for publishing spatial data and interactive mapping applications to the web. We used *MS4W* (v. 4.0), a package containing:

- *Apache* as a web server,
- *PHP* a script language originally designed for web development
- *MapServer*: CGI/ MapScript for the manipulation of geographic data

4.2.3 Openlayers:

OpenLayers (v.3) facilitate the insertion of a dynamic map into a web page like zoom and navigation functions.

4.2.4 Display:

We can use any web browser like *Mozilla Firefox* or other. Figure 5 shows the client interface of the solution we developed. Table 2 gives the details and the function of the interface elements.

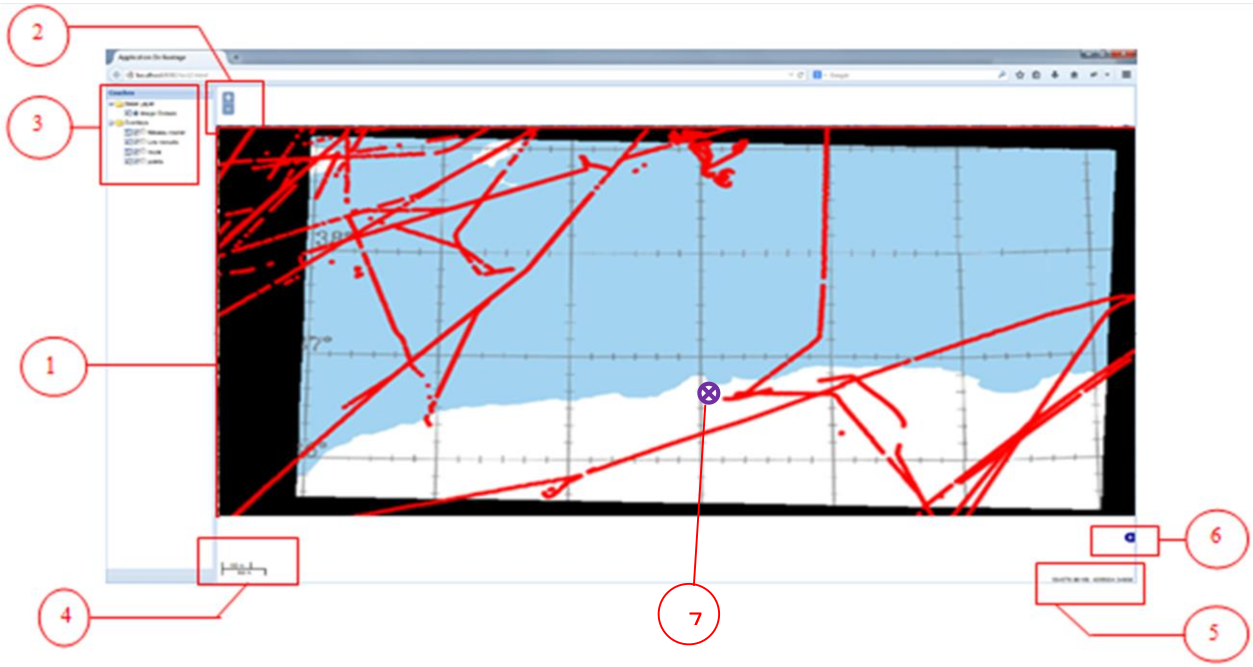


Figure 5: *Client Interface of the Proposed Solution*

Table 2: *Details of the Client Interface Elements*

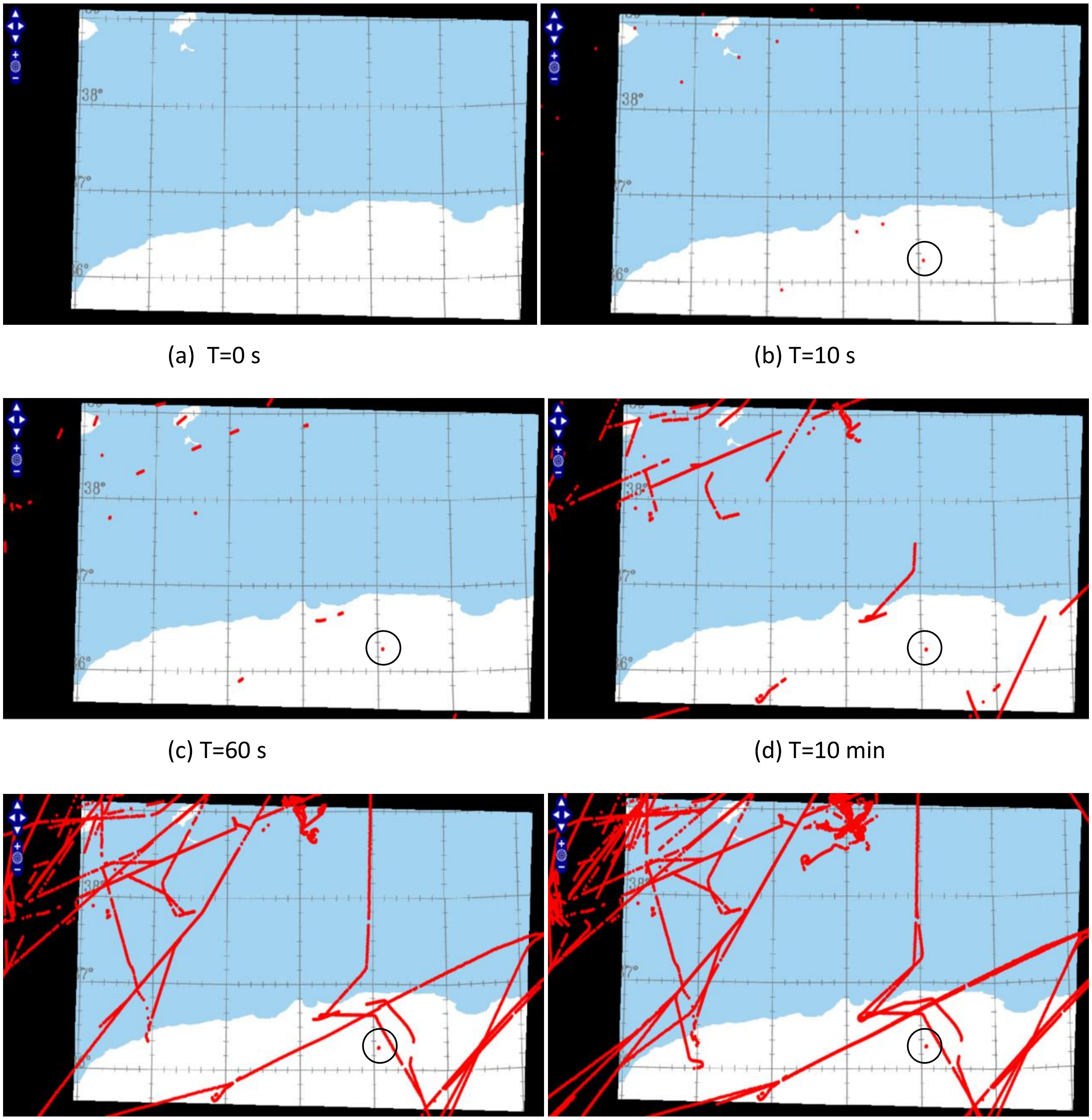
Element	Function
1	Visualization of geographical data: A large part of the interface of our system is reserved for the visualization of the geographical map. Geographical data of different types (raster and vector) are displayed.
2	Zoom and pan: You can zoom in/out on any region of the displayed map, either by using the zoom in/zoom out buttons or by using the mouse wheel. On the other hand, the pan is done by clicking and dragging with the mouse or by using the orientation buttons on the keyboard.
3	Thematic layer management: the information from the displayed map is divided into layers. The client interface manages the display of these. It is possible to display several layers simultaneously as well as to display only the background of the map.
4	Display of a scale bar.
5	Display of the geographical coordinates of the objects when the mouse hovers over them.
6	Displaying a reference map: this feature gives an overview of the map. It delimits the displayed region in relation to the entire map. This feature makes it easier to navigate the map.
7	Oued Smar ATC Radar position

5. Results and Discussion

We tested our application on the north-central area of the Algiers region in Algeria. The radar data come from the Oued Smar radar located south of the Algiers aerodrome and whose range is around 250 nautical miles (~ 460 km). The data was obtained from the Area Control Center of Algiers under the authority of ENNA, the body responsible for the management of airspace. They date from 2014 and come in the form of a text file containing more than 26000 lines of data, equivalent to just under one hour (53 minutes) of traffic data.

The traffic visualization is done on the web browser is done by inserting the following URL: http://localhost/cgi-bin/mapserv.exe?mode=browse&template=openlayers&map=/ms4w/Apache/htdocs/test.map

The update is done automatically through Openlayers. In addition, it offers navigation and zoom tools available in the display window. Figure 3 shows the evolution of traffic according to time. Aircraft positions are indicated in red. With the evolution of time, we notice the constitution of red lines that are nothing but the different positions over flown by the same aircraft. There are also some fixed points (surrounded by a black circle) that correspond to either an aircraft doing on-site (helicopter or balloon for example) or just a noise (erroneous data) from the radar. In general, the lines corresponding to this type of error have a code_3a = 1200 (unacknowledged SSR code). They can therefore be deleted from the text data file.



(a) T=0 s (b) T=10 s

(c) T=60 s (d) T=10 min

(e) T=30 min (f) T=53min

Figure 3: *Evolution of Air Traffic According to Time T.*

7. Conclusion

Our job was to create a web application simulating the evolution of air traffic data from a pseudo radar represented by a radar data server. The goal was to enable remote simulation at a lower cost. The tools used are essentially open source and the solution has the merit of being easily deployable and exploitable. For this, we used a radar data set in ASTERIX format to generate traffic data over time. Nevertheless, the solution does not allow interaction with the aircraft (change of direction for example). In addition, it is necessary to improve its interface by adding information labels for aircraft. For the future, it would be interesting to extend the work for several sources of radar data (multi radar). Finally, we plan to integrate other types of data such as flight plans or ADS data.

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