Visualization of a detailed Rocket Trajectory on a Cartographic maps based on Open Web Standards

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Abstract. *Graphics are the main means used to quickly disseminate information to a wide range of users. Due to its importance, Web applications also have to consider graphics as a major issue to embed them. However, for Web applications, issues such as interoperability pop up. Therefore, the idea of this paper is to explore existing web standards (XML, SVG, etc.) for use in visualizing a Rocket Trajectory path in a cartographic map projection. This application software deals with data obtained from a database so some animation procedures can be deployed. Zooming facilities are also enabled to verify, for example, launch pad region. A detailed trajectory analysis can be conducted by visualizing the projection of the vehicle's position in a map. Moreover, for each of the vehicle's position, other parameters such as velocity, acceleration, mass, etc. can also be seen according to the specified position. There are several ways to perform the analysis. One way is to simulate the flight evolution in a real time scale. Another alternative is to simulate the flight on a step by step basis or even based on events that will affect the trajectory. There is one more option that is to obtain the data associated to the vehicle's position by clicking a position on the map. Examples of use of this application will be presented.*

1. Introduction

Applications involving Rockets must be carefully seen in minute details, due to the fact that these vehicles reach very high velocities and therefore its position and all its parameters can change very fast. In order to analyze pre flight or post flight simulation, one should have resources based on some technologies to realize the effects of changes in a millisecond, of each parameter that refers to the current position of the vehicle.

These applications can take a significant advantage if visualization is considered, i.e., the evolution trajectory could be seen graphically. It should cater for visualizing the trajectory path in a cartographic map enabling the determination of vehicle's actual position. This visualization has already been used and it is essential for monitoring a rocket in real-time for the purpose of safety conditions [1]. However, for the purpose of analysis, one has to know step by step details, not only in a text mode, but graphically as well.

In order to make the applications available and deployable, Internet technologies can be appropriate. There are a variety of technologies that could deal with issues related to interoperability of how to envisage a tool that can eventually run among a wide variety of platforms. There are efforts in this direction and W3C (World Wide Web Consortium) proposed a set of languages that can be used within the Internet and these languages are supposed to serve as means of communications among many applications regardless of the hardware or the operating system being used. The only requirement is that the platforms that deal with such languages must have the appropriate tools installed for this purpose. Both the languages and the tools are available free of charge at the

W3C site. Moreover, extensive discussions are taking place in order to standardize these technologies.

With the interoperability in mind, a software package consisting of a tool for analyzing a rocket trajectory path with visualization features has been developed. The interoperability technologies used to develop this application are XML (Extensible Markup Language) and in particular SVG (Scalable Vector Graphics) that enables the visualization within the web.

2. Tools Description

This section is dedicated to provide a brief description of some of the open web standards used for the application, such as XML, SVG and SVG Viewer. Detailed information of these web standards can be accessed at W3C [2] site or adobe site.

XML – Just like HTML, it is a format to organize documents and data as a structure on the Web. It is meta-language, i.e., it can define other languages. However, it is not a successor of HTML.

DOM – The Document Object Model is basically an interface, used by a programming language, to access XML files. Programs and scripts can dynamically access web documents to update their content, structure and style.

SVG – It is a language that can describe two-dimensional graphics based on XML. It is not proprietary. The act of drawing by means of SVG can be dynamic and interactive. Some browsers already support native SVG, but in most of them, you need to install an appropriated plug-in in order to view any SVG objects.

SVG Viewer – The plug-in need for this application is adobe SVG Viewer [3]. Plug-in is a software that provides additional functionalities for your browser.

Scripts – PHP [4] on server side and JavaScript [5] on client side will provide more interactivity and animation.

3. Application development description

It is important to mention that this application will not calculate any rocket trajectory; it only groups the data of the specified vehicle properly and presents them in an easy way for analysis. These data could be analyzed from any part of the world, because the Internet technology is used in order to visualize the trajectory path.

Figure 1 shows a brief scheme for this application:

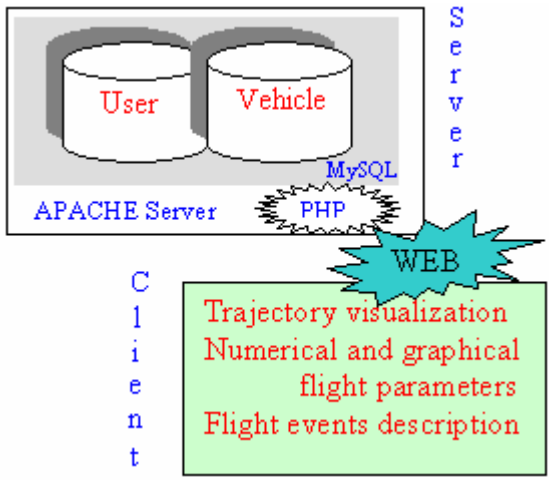

Figure 1. Application

Thus, this is a server/client application.

On the server side, a database with name and password for authorized clients has been created. Another database was created in order to contain all data that refers to the flights. This means that all the data relative to the trajectory path must be previously stored in a database. According to each flight, these data must have characteristics from vehicle and its flight always according to flight time as shown in Figure 2.

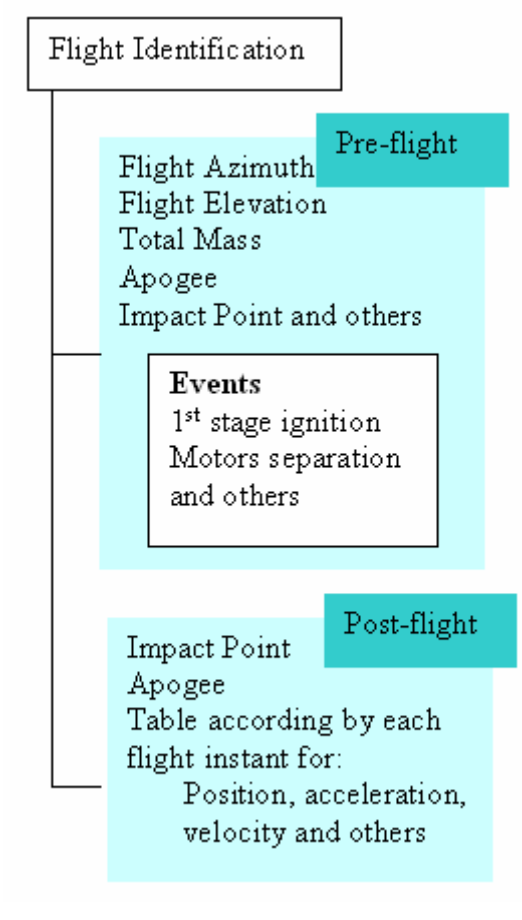

Figure 2. Vehicle database

In order to manipulate the databases, MySQL [6] is used. MySQL is one of the world's most popular open source databases, and it is more than adequate for this application. Because of the internet, these database needs a server, and Apache [7] is used. This server is also the world's most popular free software and responds to the needs of this application.

The server has one more attribution: generate dynamic pages. For this task, PHP was used. Thus, the server interacts with the client, providing the data for specific vehicle, chosen by user, which is used by the client to generate map, graphics and all compiled information about this vehicle's flight.

On the client side, the only attribution is to decide how and which information will be showed in an alpha-numeric mode or in a graphics mode. JavaScript is used to manipulate data that comes from server and through HTML presents the alpha-numeric information. The graphical information is provided by using SVG resources. SVG files are embedded in HTML page. Interactivity and dynamics could be done not only by using SVG resources but also through JavaScript.

In the next section, the details of the application will be showed.

4. Application: Step By Step Analysis

Determining rocket trajectory [8] is not an easy task for those involved with this activity. Obviously, projecting its trajectory on a map, as shown in Figure 3, is just not enough to decide whether the vehicle is going to conclude its mission. Other analyses must be available for providing information on other issues. As an example, information should be provided on whether the duration of a flight a given vehicle performed over 90 km can in fact fulfill the mission's objectives.

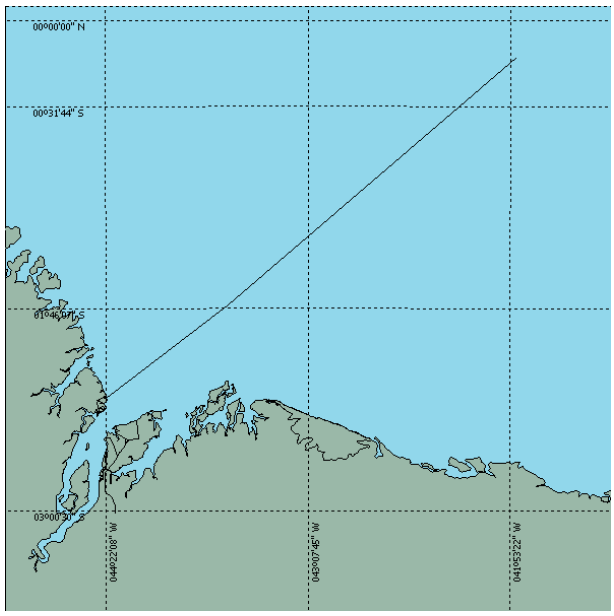

Figure 3. Alcantara Launch Center (CLA) North Brazil

More work is under progress to reconstruct [9] and visualize a vehicle trajectory in case for some reason the tracking of the vehicle is lost.

In applications involving rockets, it is normal to imagine that needs arise in learning the details of the flight at a certain instant

especially in case of occurrence of any event. For example, it might be important to see the rocket's position, velocity and its mass when an event, such as ignition of second stage, occurred. Then, with this application, the details of all parameters of the rocket can be viewed for that chosen event.

A lot of analysis can be conducted based on events or instant of flight. In order to illustrate this, consider a pre-flight analysis of a rocket reaching its apogee. This is an important point of study as usually the sounding rockets have experiments that can be fulfilled only if the rocket reaches designated altitude.

4.1 Accessing the application

As the information inserted into the database are classified, only authorized users can access and analyze those data. Therefore, users must be given special privileges previously and when they are duly authorized, a list of registered vehicles and flights appears to the user in order to select from the list for conducting analysis. Figure 4 shows a typical screen for a specified flight.

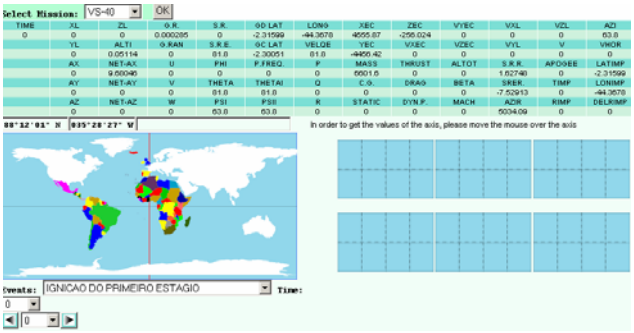

Figure 4. Initial screen

4.2 Alpha-numeric information

In order to view details about flight, one can access all numerical information according to the instant of flight or events. Thus, there is a list of events, illustrated by its descriptions associated with instant of flight at which they occur. Thus, if the event apogee was chosen, parameters according to the time of apogee will be displayed. Some of these parameters are:

- position (from launch pad and from earth center, latitude and longitude)
- acceleration and velocity
- roll, pitch and yaw rates
- mass, thrust, drag coefficient, dynamic pressure
- instantaneous impact point parameters (time, longitude, latitude and range)

These and other parameters could be viewed like in Figure 5.

TIME	XL	ZL	G.R.	S.R.
0	0	0	0.000285	0
	YL	ALTI	G.RAN	S.R.E.
	0	0.05114	0	81.8
	AX	NET-AX	U	PHI
	0	9.68046	0	0
	AY	NET-AY	V	THETA
	0	0	0	81.8
	AZ	NET-AZ	W	PSI
	0	0	0	63.8

Figure 5. Flight data

They are selected through events or instant of flight or even step by step of integration step in which the calculation was conducted. Figure 6 shows how this selection is done.

Figure 6. Time and Events selection

4.3 Trajectory path map

The application server has a XML file with world's coordinates. All coordinates are represented in terms of geodetic latitude and logintude. Therefore, the outlines of the countinents as well as the outlines of some countries are based on latitude and longitude.

Then, in order to draw the cartographic map shown in Figure 4, DOM manipulates the XML data as a structure, making it easy for JavaScript commands to deal with each country, island or lake as an object. These objects are incorporated to the computer screen in the SVG canvas. As one of the objectives of this paper is to explore existing web standards, are therefore the means through which graphics are rendered based on XML is SVG. In this technology, the space to

which drawings are rendered is known as canvas.

As this application draws cartographic maps, it does not accept any distortions and therefore, the aspect ratio was already preset so that its value is always preserved on canvas viewport.

Figure 7 shows the zoomed area around Alcantara Launching Center (CLA), and plloted the exact position of the rocket in a apogee event.

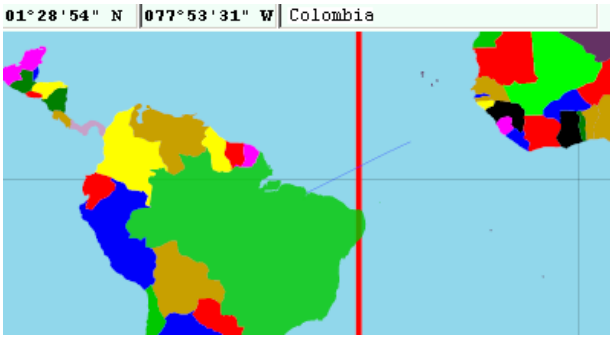

Figure 7. Time and Events selection

Due to the use of SVG resources, when the mouse drags over any object, its position is detected by the application and converted to Latitude and Longitude coordinates. The country name for its position is also detected. It is necessary to emphasize that, using SVG resources one can associate any event handlers to any object as well as to get information of all objects according to its specification in XML file. In this application, objects could be countries, lakes, islands, trajectory path and any line or path.

4.4 Graphical information

The alpha-numeric table provides information about all parameters. As one can see in the Figure 5, all the parameters are listed for a given instant of flight. It would be interesting if the table also included a certain parameter for all the instants of flight. It is normal to show some figures graphics relative to time, but there is a lot of comparison that could be done, which will not be discussed in this paper.

A picture such as the one shown in Figure 8 (Total Acceleration by Time and Altitude by Range), are some examples for analysis.

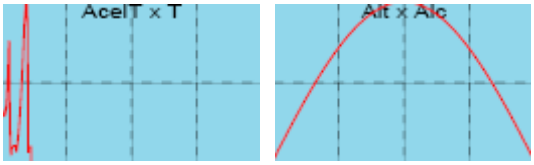

Figure 8. AccelT x T , Alt x Range

There are fixed compositions of these parameters. Therefore, all the graphics part is done automatically when a flight is chosen. Efforts will be made, in future versions, for an user to choose to organize the graphics and the number of graphics that will be displayed.

As these graphics are plotted using SVG resources, zoom out and zoom in could be done in order to analyze details at a given instant of flight.

For security reasons, all data used to plot graphics and maps are for illustration purposes only, i.e., these data are not from a real flight.

5. End user

One of the major uses for the tool described in this paper is for those that are responsible to determine the best trajectory path for a given rocket based on its restrictions.

6. Conclusion

Use of computer graphics, if properly applied, presents a gracious interface to many a application and invites the users (even laypersons to computers) to interact with the application without any fear, quite natural to those not used with computers. Definitely, rocket trajectory is such an application that should make a full use of the potential of computer graphics.

However, within the context of the paper, it was essential to develop the application for use over the Internet by space-related community. Interoperability technologies such

as XML and in particular SVG to deal with graphics over the web have come to the rescue.

It was shown that web standards could be and must be adopted for such applications. The technologies used and supporting software needed to develop for the proposed application are free of charge and can be downloaded from several sites. Moreover, discussions over these issues are going on in order to standardize such technologies as well as the supporting tools.

Use of these technologies encourages teamwork. Several agreements have been established among countries in order to accomplish a same mission. Therefore, based on the product described in this paper, a study can be conducted over a same database from any part of the world.

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