B.Eng. Dissertation

3D PLOTTING OF AIRCRAFT ATTITUDE

Submitted by
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Muhammad Omer Iqbal: *3d Plotting Of Aircraft Attitude,* Bachelor of Engineering (Computer Engineering), © November 2013

ABSTRACT

Air accident investigations usually involve reading and interpreting large volumes of flight data. Visualising this data, especially in a geographic context makes its analysis easier. Therefore the Air Accident Investigation Board (AAIB) needed a tool that would render a 3 dimensional model of flight data from their datasets. The data includes measurements like latitude, longtitude, altitude, heading, roll, thrust etc over time. To meet this criteria I designed a Clojure based application that takes a dataset in csv format and renders aircraft attitude over time on a map. The application generates a KML (Keyhole Markup Language) file which can be opened on Google Earth and displays a 3d model of the data.

SUBJECT DESCRIPTORS:

- Specialized information retrieval
- Information visualization
- Geographic visualization

KEYWORDS: Clojure, KML, Visualisation, Aircraft Attitude, XML generation, 3d Modelling

PUBLICATIONS

Some ideas and figures have appeared previously in the following publications:

Put your publications from the thesis here. The packages `multibib` or `bibtopic` etc. can be used to handle multiple different bibliographies in your document.

We have seen that computer programming is an art,
because it applies accumulated knowledge to the world,
because it requires skill and ingenuity, and especially
because it produces objects of beauty.

— **?** [**?**]

ACKNOWLEDGEMENTS

I would like to thank my supervisor, Dr. Colin Tan for recommending this project to me and for giving me full independence in the implementation. I would also like to thank Mr. Steven Teo of AAIB for his prompt and helpful feedback over the course of the project.

I also would like to extend my thanks to the clojure community in general for releasing such a magnitude of powerful open source libraries that made this project incredibly fun to work on.

Lastly, I would like to thank Mina, my girlfriend, for being patient.

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LISTINGS

ACRONYMS

DRY Don't Repeat Yourself

API Application Programming Interface

UML Unified Modeling Language

KML Keyhole Markup Language

AAIB Air Accident Investigation Board

[November 3, 2013 at 3:34 – classicthesis version 2.0]

Part I

THE PROBLEM

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1 INTRODUCTION

1.1 BACKGROUND

Aircraft systems record large quantities of data during flight. A lot of this data is necessary in the system 's proper functioning. It takes an even more significant role when investigating air accidents. As this data establishes the causes behind those accidents, it aids measures to prevent such accidents from occurring. That is the primary reason for why recovery of Flight Data Recorders [1] is usually a very high priority for aircraft investigations.

The data itself features many components tracked over time, including but not limited to the following[2]:

- Latitude
- Longtitude
- Altitude
- Heading
- Pitch
- Roll
- Engine Thrust
- Throttle Lever Position

As is probably evident, analyzing this largely numeric data by itself would be a painstaking task. Primarily because finding patterns in numbers through observation is inherently difficult. Also because the data set is of a substantially large size [3].

Therefore the need for a tool to visualise this data becomes immediately obvious.

The Air Accident Investigation Board (AAIB), a branch of Singapore's Ministry of Transport performs analysis on such flight data, and requested an application that would render relevant flight data quickly and in a portable manner.

1 Popularly referred to as 'Blackboxes'
2 The following components were part of the sample dataset I was given for testing.
3 I will be cautious before calling it "Big Data".

[November 3, 2013 at 3:34 – classicthesis version 2.0]

1.2 SYSTEM REQUIREMENTS

AAIB needed the application to meet certain criterias and contain certain core features. These included:

1. GOOGLE EARTH Compatibility. Google Earth is a popular "virtual globe, map and geographic information program". It provides detailed 3d projections of Google's satellite images on a spherical globe, overlaid with huge quantities of textual and pictorial data varying from international boundaries to streets. There are many good reasons for this requirement including:
   - Cross Platform. It works and is supported on Windows, OSX and Linux [4]
   - Extensible through the Keyhole Markup Language (KML) [5]
   - Free[6]
   - AAIB's familiarity with it
   - Offline use. This is quite important as internet access is not guranteed on accident sites
2. CSV[7] based input. The system should be able to use large datasets encoded in CSV.
3. The system should display the data in its geographical location as vectors. The visualization should be able to reflect the actual data in an intuitive way. For instance, vectors at each data point should represent roll, heading, engine throttle
4. Users should be able to select which vectors they want to view.
5. The data points should be manually adjustable from within google earth. This is particularly relevant for data points near landing strips, where measurement errors may cause an offset in the rendered visualization

4 Atleast the desktop version is supported on all three major Operating Systems.
5 A lot more on this later
6 As in beer, not speech
7 Comma Separated Values

Part II

CHOOSING THE STACK

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2 LITERATURE REVIEW

As with any project, the first few stages of the project involved researching on existing technologies that either implemented the features specified in by AAIB in their requirements, or aided in developing those features. As Google Earth compatibility was a major requirement for the project, my research started with exploring methods to render custom data on Google Earth's platform.

2.1 KEYHOLE MARKUP LANGUAGE

The Keyhole Markup Language (*KML*) is a subset of XML, used to display geographic data in an Earth Browser, like Google Earth. It uses a tag based structure with nested elements that represent certain geometric and descriptive constructs. The KML reference is very reasonably documented with sample code demonstrating it's usage.

KML supports rendering the following features:

1. Placemarks
2. Descriptions
3. Ground Overlays
4. Paths
5. Polygons

2.1.1 *Test for a Subsection*

Note: The content of this chapter is just some dummy text.

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2.2 ANOTHER SECTION IN THIS CHAPTER

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1 De web nostre historia angloromanic.

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This statement requires citation **?** [**?**].

2.2.1 *Personas Initialmente*

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Table 1: Autem timeam deleniti usu id. **?**

2.2.1.1 *A Subsubsection*

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A PARAGRAPH EXAMPLE Etiam euismod. Fusce facilisis lacinia dui. Suspendisse potenti. In mi erat, cursus id, nonummy sed, ullamcorper eget, sapien. Praesent pretium, magna in eleifend egestas, pede pede pretium lorem, quis consectetuer tortor sapien facilisis magna. Mauris quis magna varius nulla scelerisque imperdiet. Aliquam non quam. Aliquam porttitor quam a lacus. Praesent vel arcu ut tortor cursus volutpat. In vitae pede quis diam bibendum placerat. Fusce elementum convallis neque. Sed dolor orci, scelerisque ac, dapibus nec, ultricies ut, mi. Duis nec dui quis leo sagittis commodo.

A. Enumeration with small caps

B. Second item

Another statement requiring citation **?** [**?**] but this time with text after the citation.

2.2.2 *Figure Citations*

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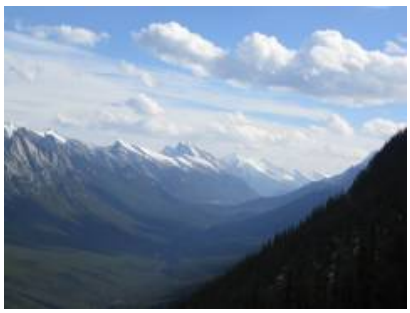
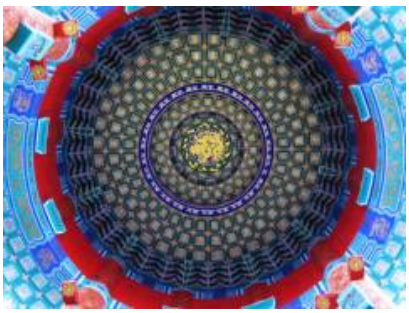
(a) Asia personas duo.

(b) Pan ma signo.



(c) Methodicamente o uno.



(d) Titulo debitas.

Figure 1: Tu duo titulo debitas latente.

3 MATH TEST CHAPTER

Aliquam lectus. Vivamus leo. Quisque ornare tellus ullamcorper nulla. Mauris porttitor pharetra tortor. Sed fringilla justo sed mauris. Mauris tellus. Sed non leo. Nullam elementum, magna in cursus sodales, augue est scelerisque sapien, venenatis congue nulla arcu et pede. Ut suscipit enim vel sapien. Donec congue. Maecenas urna mi, suscipit in, placerat ut, vestibulum ut, massa. Fusce ultrices nulla et nisl.

3.1 SOME FORMULAS

Due to the statistical nature of ionisation energy loss, large fluctuations can occur in the amount of energy deposited by a particle traversing an absorber element[1]. Continuous processes such as multiple scattering and energy loss play a relevant role in the longitudinal and lateral development of electromagnetic and hadronic showers, and in the case of sampling calorimeters the measured resolution can be significantly affected by such fluctuations in their active layers. The description of ionisation fluctuations is characterised by the significance parameter κ, which is proportional to the ratio of mean energy loss to the maximum allowed energy transfer in a single collision with an atomic electron:

You might get unexpected results using math in chapter or section heads. Consider the `pdfspacing` option.

$$\kappa = \frac{\xi}{E_{max}} \tag{1}$$

E_{max} is the maximum transferable energy in a single collision with an atomic electron.

$$E_{max} = \frac{2m_e\beta^2\gamma^2}{1 + 2\gamma m_e/m_x + (m_e/m_x)^2},$$

where $\gamma = E/m_x$, E is energy and m_x the mass of the incident particle, $\beta^2 = 1 - 1/\gamma^2$ and m_e is the electron mass. ξ comes from the Rutherford scattering cross section and is defined as:

$$\xi = \frac{2\pi z^2 e^4 N_{Av} Z\rho\delta x}{m_e\beta^2 c^2 A} = 153.4 \frac{z^2}{\beta^2}\frac{Z}{A}\rho\delta x \quad \text{keV},$$

where

1 Examples taken from Walter Schmidt's great gallery: http://home.vrweb.de/~was/mathfonts.html

z	charge of the incident particle
N_{Av}	Avogadro's number
Z	atomic number of the material
A	atomic weight of the material
ρ	density
δx	thickness of the material

κ measures the contribution of the collisions with energy transfer close to E_{max}. For a given absorber, κ tends towards large values if δx is large and/or if β is small. Likewise, κ tends towards zero if δx is small and/or if β approaches 1.

The value of κ distinguishes two regimes which occur in the description of ionisation fluctuations:

1. A large number of collisions involving the loss of all or most of the incident particle energy during the traversal of an absorber.

   As the total energy transfer is composed of a multitude of small energy losses, we can apply the central limit theorem and describe the fluctuations by a Gaussian distribution. This case is applicable to non-relativistic particles and is described by the inequality $\kappa > 10$ (i. e., when the mean energy loss in the absorber is greater than the maximum energy transfer in a single collision).

2. Particles traversing thin counters and incident electrons under any conditions.

   The relevant inequalities and distributions are $0.01 < \kappa < 10$, Vavilov distribution, and $\kappa < 0.01$, Landau distribution.

3.2 VARIOUS MATHEMATICAL EXAMPLES

If $n > 2$, the identity

$$t[u_1, \ldots, u_n] = t\big[t[u_1, \ldots, u_{n_1}], t[u_2, \ldots, u_n]\big]$$

defines $t[u_1, \ldots, u_n]$ recursively, and it can be shown that the alternative definition

$$t[u_1, \ldots, u_n] = t\big[t[u_1, u_2], \ldots, t[u_{n-1}, u_n]\big]$$

gives the same result.

Part III

APPENDIX

A

APPENDIX TEST

Aliquam lectus. Vivamus leo. Quisque ornare tellus ullamcorper nulla. Mauris porttitor pharetra tortor. Sed fringilla justo sed mauris. Mauris tellus. Sed non leo. Nullam elementum, magna in cursus sodales, augue est scelerisque sapien, venenatis congue nulla arcu et pede. Ut suscipit enim vel sapien. Donec congue. Maecenas urna mi, suscipit in, placerat ut, vestibulum ut, massa. Fusce ultrices nulla et nisl.

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A.1 APPENDIX SECTION TEST

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Table 2: Autem usu id.

Listing 1: A floating example

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for i:=maxint to 0 do
begin
{ do nothing }
end;
```

viverra aliquam risus. Nullam pede justo, molestie nonummy, scelerisque eu, facilisis vel, arcu.

A.2 ANOTHER APPENDIX SECTION TEST

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COLOPHON

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http://code.google.com/p/classicthesis/

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DECLARATION

Put your declaration here.

Singapore, November 2013

Muhammad Omer Iqbal,
November 3, 2013