JDataViewer 3D Extension: 

*Design, Development and Usability Test*

**Student**  Zereyakob Makonnen  
**Year**  2012  
**Supervisor**  Prof. Gilles Falquet
Analysis conclusions .................................................................44
Prospective.................................................................................44
Bibliography ...............................................................................45
APPENDIX A...............................................................................46
Mouse interactions ......................................................................46
Effectiveness-Data........................................................................46
Efficiency-Data............................................................................46
SATISFACTION –DATA...............................................................47
Appendix B.................................................................................48
ACKNOWLEDGMENT
INTRODUCTION
This master thesis project took place at CERN (European Center for the Nuclear Research) (1).

I worked within the Data Management (DM) section which is a part of the Control (CO) group in the Beam (BE) department.

BE is the department responsible for the generation of "Beam", acceleration, diagnosis, control and optimization of performance for the CERN accelerators (PS, SPS, LHC, LINAC etc.).

The group CO is responsible for the specification, the conception, the integration and the installation of the infrastructure of control for all the accelerators but also for their lines of transfers and their areas of experiment.

The Section DM takes care of the database management of the data for all the systems belonging under the BE department.

I have worked on a new functionality concerning the CERN JDataViewer library. More precisely I've worked on an extension of this java library, to allow the data visualization also in 3D.

DOMAIN

LHC
At present the CERN is one of the most important centre of research. Its research in the physics of particles (that supplies bases to all the theory of the physics) pushed it to the construction of one of the biggest instruments all over the world the LHC (2).

The LHC is not the first circular accelerator realized to the CERN. In the order were built the Proton Synchrotron (PS the 60s), the Super Proton Synchrotron (SPS 70s-80s), Large Electron-Positron (LEP 90s) this last one replaced by LHC, and they work respectively on 28 GeV (Giga electron Volt), 450 GeV and 750 GeV.

Several experiments are made beside of those which are considered the most important (CMS, ALICE, ATLAS) (3). The way all the experiments work is as follow:

- Particles are accelerated at the beginning by a linear accelerator which is different according to the type of experiment, with particles of ions (LINAC 3) and with protons (LINAC 2).
- Particles are accelerated by the first one the PS circular accelerators.
- Particles supplied by the PS are accelerated a third time by SPS which supplies at the same time the LHC and the other experiments which work on fixed targets (for example for the research on neutrino, led by the Gran Sasso National Laboratory).
- Particles are accelerated a fourth time by the LHC. The peculiarity is that particles supplied by the SPS are alternately accelerated clockwise and counter clockwise, and the "Bunches" of particles travel in two different beams.
- When particles reach the optimal speed, both beams are join, in the points of the LHC where are placed the experiments, to allow the collision of particles.

Below you can see an image of the CERN accelerator complex described early.
Figure 1 - LHC accelerator Complex

**LOGGING SYSTEM**

The LHC is a huge machine with an unimaginable complexity that needs to be carefully monitored and controlled. Each of the subsystems has its own data acquisition system to track parameter values over time. Hundred-thousands of signals coming from equipment surveillance and beam observation need to be “logged” in a central database to carefully examine the behavior of the machine. Additionally, end-users should be able, through this database, to correlate heterogeneous information, visualize and extract any data, compare over time, examine trends, find patterns and discover relationships between apparently unlinked parameters. In this way, the LHC Logging project (4) was launched, with the objective to log heterogeneous time series data, including: Cryogenics temperatures, magnetic field strengths, power dissipation, vacuum pressures, beam intensities, positions...

The logging project started in 2001 and the first operational implementation was used in autumn 2003. The importance of such a logging system was already demonstrated on the previous big accelerator LEP. At that time, unexpected influences such as the tides due to the moon and the TGV passing in Geneva that influenced the behavior of the LHC could be confirmed with the Logging System. The LHC Logging System was built and it is currently maintained by the data management section.

**Data Sources:**

For industrial services such as cooling, ventilation, vacuum, cryogenics, SCADA systems (5) built on top of PLCs are used to monitor part of the data coming from the LHC. The SCADA systems are built using PVSS technology.

Clients have built application based on this system to send their data to the Logging Database. The most important part of the data (more than 90%) logged in the Logging Database comes from these clients. PVSS is able to filter some data and then only data of interest are sent to the Logging Database.

A second category of clients are mostly beam-related instrumentation for which the data acquisition passes through custom home-made applications without local persistence. These clients, who cannot filter their data, have to send their data to another database, the Measurement Database for data persistence. Since the data is unfiltered it is sent at a higher rate with raw time series data measured at up to 2Hz. This database will filter interesting data and send it to the Logging Database, where it will be stored for the long term. Whereas the Measurement Database stores data up to 7 days, the Logging Database must do it for the LHC’s life time; this means at least 20 years.

The data coming from the Measurement represents currently almost 10 % of the Logging data. Additionally, the Measurement Database is also able to create some statistics about the performance of the accelerator. Finally the rest of the data (less than 1%), comes from the Technical Services department, which is responsible for systems such as electricity and water.

**Data Extraction:**

In consequence of the gigantic amount of data and the complexity of the database, a dedicated Java tool was built to extract the data in a user-friendly and efficient way. This GUI tool, baptized TIMBER (6), makes easy to select variables of interest and analyze them in many ways such as statistics, charts, etc... In addition, for specialized systems and applications that need to directly access logged data, Java and PL/SQL data extraction APIs are provided.
PROBLEM STATEMENT

The aim of this thesis project is to create a 3D graphic library to display time series data in a chart. This library will replace the actual one (ILog) used by TIMBER, the Logging System user interface. Therefore we need to:

- Design the new graphic library that allow 2D and 3D visualization of the data
- Develop all the functionalities provided by ILog
- Integrate it with TIMBER

Since one of the main constraints is to keep the same look and feel provided by ILog, no new methodology of Time series Data visualization will be proposed.

This works will:

- Prove that JDataViewer is as good as ILog
- Compare the performance of both library
- Evaluate the Usability of the new library

CHAPTER OVERVIEWS
In the first chapter an introduction to the domain where this project took place and an overview of the problematic that this work will tackle will be given.

In the second chapter a state of the art of the most recent research work, concerning the visualization of time series data, will be given. Also, the state of the art of the Java graphic library used at CERN, the problems concerning the Logging System GUI and the possible solutions will be discussed.

In the third chapter requirements, use cases and the architecture of the new library will be presented.

The fourth chapter is dedicated to the development and the integration with the present libraries, pointing out the most important part of this phase.

The fifth chapter is dedicated to the evaluation of the new library, where a description of how the evaluation has been done and the comparison results between the actual library and the new one will be presented.

The last chapter is dedicated to the conclusions, where the problematic found and the prospective about the work done will be presented.
STATE OF THE ART
In this chapter a description of what is the state of art concerning The Time-series data Visualization methodologies, JDataViewer (7) and TIMBER. We will discuss also all the problems that the user is facing with the actual visualization system.

CLASSICAL VISUALIZATION METHOD
The classical visualization method that have been used for the first time in the statistic domain (1700s), are still the most used nowadays in almost all the fields.

SCATTER:
In scatterplot the data is displayed as a collection of points, each having the value of one variable determining the position on the horizontal axis and the value of the other variable determining the position on the vertical axis. Scatter plots show the relationship between two variables by displaying data points on a two-dimensional graph. The variable that might be considered an explanatory variable is plotted on the x axis, and the response variable is plotted on the y axis.

Figure 3 - Edmund Halley’s 1686 bivariate plot of the theoretical relation between barometric pressure (y) and altitude (x).

LINE CHART:
A line chart or line graph is a type of chart, which displays information as a series of data points connected by straight line segments. It is a basic type of chart common in many fields. It is an extension of a scatter graph, and is created by connecting a series of points that represent individual measurements with line segments. A line chart is often used to visualize a trend in data over intervals of time – a time series – thus the line is often drawn chronologically.

Mendeleev's periodic table, for example, allowed him to predict the physical and chemical characteristics of Gallium (Ga) and Germanium (Ge) before they were discovered decades later. Mendeleev’s table, however, arranged the elements only by a serial number, denoting an atom’s position in a list arranged by increasing atomic mass.
BAR CHART:

Bar charts are used for marking clear data which has discrete values. A bar chart is very useful for recording certain information whether it is continuous or not continuous data. Bar charts also look a lot like a histogram. They are often mistaken for each other.

The first bar graph appeared in the 1786 book *The Commercial and Political Atlas*, by William Playfair (1759-1823). Playfair was a pioneer in the use of graphical displays and wrote extensively about them.

![Figure 4 - Moseley's X-rays and the concept of atomic number](image)

![Figure 5 - William Playfair's 1821 time series graph of prices, wages, and ruling monarch over a 250-year period.](image)
TIME-SERIES DATA VISUALIZATION

When we speak of time-series data we mean data that has dependencies or somehow is correlated with the time.

Usually we differentiate between nominal, ordinal, and quantitative data, of these, whether an inherent ordering or a meaningful distance metric is given for data or not.

As Wolfgang Muller and al. point out on their work about Time-Oriented Data (8) there are different aspects of time that has to be taken in consideration, in order to choose the appropriate visualization method for this kind of data. They listed a series of criteria adapting the work done by Frank (9) and propose different visualization method according with the criteria listed below and the user need:

- Linear Time vs Cyclic Time
- Time Points vs Time Intervals
- Ordered Time vs Branching Time vs Time with Multiple perspective

As an example if you have a time series data and the need is to find the picks, the best way is to show the data with a Time Series Plot. But when the need is to find a periodic pattern a Spiral Graph (10) correctly configured is the best visualization method.

![Time Series Diagram and Spiral Graph](image)

**Figure 6 - Time Series diagram and SpiralGraph**

**TIME WHEEL VISUALIZATION METHOD**

Interesting is the work done by C.Tominski and al. (11). Where they propose the TimeWheel visualization method. Differently from time series diagram that required that the attributes to be visualized have a common, or at least a similar value range, this technique allow presenting multiple time-dependent attributes (Multivariate variable) with different value ranges.
The TimeWheel is a multi-axes representation for visualizing multivariate data over time. This is achieved by putting a time axis to a prominent position in the center of the display. A set of axes that encode time dependent attributes is circularly arranged around the central time axis. For each time point in the considered data, lines descend from the time axis to the corresponding points on each of the attribute axes. The TimeWheel can be rotated to bring different attributes into the focus.

**LARGE SCALE TIME-VARYING DATA VISUALIZATION METHOD**

Very often time-varying data it is presented as a polyline, and when we need to represent thousands of values it is very difficult to put them in limited space. It is even worse if we need to plot different variables in order to compare them. Maiko Imoto and Takayuki Itoh present recently a work (12) where this kind of problematic is tackled. The works present a 3D time-varying data visualization technique, which firstly order the time-varying data base on their similarity (using a clustering algorithm).

It then provides two views, one showing the whole time-varying data, the other showing the partial data extracted after a selection of the interval of interest from the first views (see picture below).
Moreover they improve this technique applying SAX (Symbolic Aggregate approXimation) to detect similar or outlier pattern.

**JDataViewer**
The JDataViewer is a Java-based charting library developed at CERN, with powerful, extensible and easy to use function editing capabilities. Function edition is heavily used in Control System applications, but poorly supported in products available on the market. The JDataViewer enables adding, removing and modifying function points graphically (using a mouse) or by editing a table of values.

The library provides all typical 2D plotting types (scatter, polyline, area, bar, HiLo, contour), as well as data point annotations and data indicators. A clear API is provided to configure and customize all chart elements (colors, fonts, data ranges ...).

Since its initial implementation in 2005, the library has been very well perceived by developers. The number of applications depending on it has grown rapidly over the past few years. Diversity of uses has also increased over time, changing from trivial signals displayed offline, to applications used to show real-time signal, and GUIs displaying data coming with a relatively high frequency (10-20Hz).

Today, JDataViewer is used by almost all operational applications (requiring charting) in the Controls group at CERN and has been adopted by the LHC experiments.

**Architecture**

**Chart:**
All the drawings are made on a centrally placed chart area called Area. In the centre of the area there is a plotting rectangle surrounded by scales. The chart can contain a single X scale and one or more Y scales. The Legend component can be drawn in two different forms as a floating panel that can be dragged on the plotting area (by default with a semi-translucent background) or as a panel placed on the side of the chart. Its visibility, position and paint attributes are configurable.

![Figure 9 - Chart structure](image)

In the sketch here above it is possible to see how a chart is structured.

Among its principal components we can find:
- 2D Area
- DataSource
- Interactors
- Renderers
- Scales

2D Area:
The area component is in charge of all the aspects concerning the painting of:

- Plots
- Scales

In the image here under you can see an example; where the Drawing Area of is marked in red.

![Figure 10- JDVE 2D Area](image)

**DataSource:**
In order to display a plot in the chart one has to first create an instance of the DataSet interface that represents a single series of data points \((X, Y)\).

All data sets which should be displayed using the same plot type (e.g. as poly lines) must then be put into a DataSource which is simply a container for a group of DataSets. Such DataSource can then be connected to an appropriate chart renderer, which draws all series of data points.

**Interactors:**
An Interactor is a component that allows the user to interact with the chart through the standard input devices. At every event of the mouse or the keyboard all the Interactors associated to the chart are activated.

Some Interactors are already available to cover the basic interaction, like:

- **DataPickerInteractor**: that displays as a tooltip the coordinates, data set name and other custom information for the point the mouse is hovering over
- **ZoomInteractor**: that zooms in and out selected regions of the chart (with Click and Drag)
- **CursorInteractor**: that can be used to graphically select a single value or a data range.
Renderers:
A render is the component in charge to draw a plot using the values contained in the DataSource associated with them.

In JDataViewer are available some of the most common renders as you can see from the previous image (Figure 3):

- PolylineChartRenderer
- BarChartRenderer
- ScatterChartRenderer
- AreaChartRenderer

Scales:
The scale has many configurable attributes like title text, title position and rotation, foreground color, tics size, layout etc. Grids are associated with scales. All lines drawn by every grid follow step and substep values of corresponding scale. Similarly, like in case of the Scale, one can configure all visual attributes of the Grid like visibility, stroke or color.

Data Viewer:
Another important component is DataViewer that offer more advanced functionalities, allowing the user to be able to visualize more than one chart at a time and to supply an help setting and managing the application layout in easy way.

Figure 11 - JDVE

TIMBER
As I said in the introduction chapter the Logging System supply a Java API and a graphic tool in order allow the retrieving of the data stored. TIMBER is the Logging System graphic user interface used by...
the operator to extract in an easy way the data from this complex system.

![Image of TIMBER software interface]

**Figure 12- TIMBER**

**PROBLEMS**
Let’s have a look at the problematic that the TIMBER developers had to face.

**Why ILog:**
The reason why ILog is used on TIMBER it is because at that time there was the need to implement a new functionality that allowed his users to extract and visualize the data, in a graphic form, and to interact with them.

Up to that moment the users had the possibility to extract the data and save them on CSV file or visualize the plots using 2D images.

The data structure of the variables saved by the "Logging system" can differ.

We can identify two types of variables:

- "Numeric" with two dimension
- "Vector Numeric" with three dimension

The "Numeric" variables foresee only a value (measure) taken at a certain instant (timestamp).

The "Vector Numeric" variables foresee in their structure more than a value (measure), which are referenced by an index, taken at a certain instant (timestamp). The third dimension in this case is given by the index of the "Vector Numeric", that allow to identify the point.

Because of their structure the "Vector Numeric" variables need to be visualized on 3D.
Unfortunately during the development of TIMBER the graphic library JDataViewer, didn’t exist yet. Therefore the developers chose an obvious solution that foresaw the use of the third part library, ILog from IBM.

**Problem 1- License fee:**
The use of IBM-ILog library oblige every year the payment of a license fee.

**Problem 2- Performance lack:**
The visualization of the data and the interaction with the 3D chart is very slow. This is probably due to the increase of the data that the “Logging System” is able to store. During the last years the frequency with which some data are taken is increased, that means an increase of the data to visualize on the graph 3D, that it is translated in a great number of calculations and of point to display.

**Problem 3- User denies:**
Some users refuse to use 3D chart on TIMBER because it is not performing as expected during the chart loading and the interaction (rotation, zoom, etc...). To compensate this lack the users use TIMBER just to export the data and use them then with other products for the graphic visualization of the data.

**Solution**
What we need is a library that doesn’t involve payments of licenses; therefore either an homemade or an open source solution could be the best choice. The library should supply at the same time functionalities for both 2D and 3D data visualization and possibly mature enough to be reliable.

**Conceptual Design**

**Requirements**
The requirements discuss on this chapter take in consideration only the request coming from the TIMBER developers.

**Context:**
Since TIMBER is the application that will start to use this new library, better to talk in a bit more details about what are his main functionalities and for which reason is needed the use of a data visualization library.

TIMBER as we said is the GUI of the Logging System. Its main functionalities concern mainly the extraction of the data from the logging systems. This application has been designed to help the final users to retrieve the data stored in order afterwards to analyze them and do some monitoring.

Since the Logging systems has a concept of variable, where the data stored is associated with it and can be referenced using the name of the variable, there are two way to find the variable from which get the data.
This application supply lots of way to establish the criteria to extract the data, once you have found your variables. There are two main criteria that are very often used.
Concerning the output provided by TIMBER: the user can extract the data and choose among three of the following options.

- **Statistic**: Where the data is show on the screen in a table.
- **External file**: The data are exported in an external file.

![Figure 18 - Output file from TIMBER](image)

- **Chart**: The data are show on a chart plotting the different variables.

![Figure 19- Chart output from TIMBER](image)
As you can see one of the functionalities is to show as output the data in a chart where the data is plot. It is for this functionality that the data visualization library is used.

**OBJECTIVES:**
Replace the actual data visualization library with a product that doesn't involve payments of licenses; therefore either a homemade or an open source solution could be the best choice. The library should supply at the same time functionalities for both 2D and 3D data visualization and possibly mature enough to be reliable.

Since this new library should replace the existing one used for the data visualization, the main requirements for the TIMBER developers is to have the same functionalities offered by ILog. In this way an introduction of big changes to the developers and the users will be avoided.

**USER REQUIREMENTS:**
Some of the functionalities are specific for one of the two context 2D or 3D some other are applicable on both.

<table>
<thead>
<tr>
<th>Feature</th>
<th>2D</th>
<th>3D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time series charts</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Multiple plot styles (poly-line, scatter, stair, area)</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Logarithmic scale</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Toggle Grids</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>1 or Many Axis</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Toggle display of cursor coordinates</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Zoom area</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Zoom X or Y axis individually</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Zoom history with step back/forward functionality</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Zoom to original display</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Panning chart with right-click</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Local Zoom</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Cross-hairs</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Save to image file</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Print option</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Change scale min/max sizes</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>3D rotation, elevation, depth, lighting</td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

**NONFUNCTIONAL REQUIREMENTS:**
The actual library do not react in a reasonable time when the user interact with the on a 3D chart using the “Area” plot style is used and there are more than 1000 points to be show.

At the moment only up to 20 Datasets can be plotted. This is quite annoying for some of the final users that need to work with more than 20 datasets.

Constraints:

1. Reducing the reaction time on 3D with more than 100 0 point and using the “Area” plot style.
Use Cases
This chapter is dedicated to the Use Cases. I will give initially a description of all the Use-Cases organizing them according with the visualization type of the data on which should be applied (2D, 3D or both). Then two Scenarios will be presented.

TIMBER User
Represents the users that use TIMBER to extract the data from a Numeric or VECTOR NUMERIC variables and see the output as a Chart

USE CASE CHART INTERACTIONS
Represents all the interactions in commons between 2D and 3D charts

![Diagram of chart interactions]

**Figure 20- Commons Chart interactions**

**Change Visualization**
The User changes the type of visualization from 2D to 3D and vice versa.

**Apply Logarithmic Scale**
The Y scale axis is changed from linear to logarithmic and vice-versa.

**Change Plot style**
**Area:** The Plot style is changed showing the Area under the plot line

**Polyline:** The plot style is changed showing the plot line eventually with a marker on the Data-Point.

**Bar:** The plot style is changed showing a Bar for reach value (Histogram) in the Dataset.

**Scatter:** The plot style is changed showing the just the points (Marker) in the Dataset.
**Stairs:** The plot style is changed showing the plot line like a stairs, where the lines connecting the points of the Datasets a not strait line.

**Toggle grid**
Hide and show the Grid of the chart.

**Save to image**
The Chart is saved as an image.

**Print Chart**
The chart is printed.

**Change Scale**
The X and Y scale is changed based on the min and max values passed as parameters.

**Zoom**
**Restore Zoom:** The view of the chart is restored as it was before the first zoom was applied.

**USE CASE 3D INTERACTIONS**
Represent all the interaction that the user can have with a 3D chart.

---

Figure 21 – Chart 3D interactions

**Rotate:**
- **Horizontal Rotation:** The position of camera in the 3D chart is changed. Allow to see the chart from the left, the front or the right side.
- **Vertical Rotation:** The position of the camera in the 3D chart is changed. Allow to see the chart from the bottom, front or top side.

**Zoom 3D**
**Zoom In:** The camera in the 3D chart is moved backward, giving the impression to move towards the 3D objects in the chart.
**Zoom Out:** The camera in the 3D chart is moved backward, giving the impression to move away from the 3D objects in the chart.

**Change Gap**
The gap between the Datasets is changed: A space between the Dataset is visible when this value is bigger than 0.

**USE CASE CHART 2D INTERACTION**
Represent all the interaction that the user can have with a 2D chart.

![Chart 2D Interactions Diagram](image)

**Figure 22 – Chart 2D Interactions**

**Toggle 1 to many Axis**
When activated the chart provide multiple Y scales, one for every dataset. When deactivated all the datasets are synchronized with only one Y scale.

**Zoom 2D**

**Local Zoom:** The Zoom is applied only in part of the plot.

**Zoom Area:** The all plot is zoomed on the area drawn by the mouse.

**Panning**
The plot is shift on the X and Y axis; only if there has been previously a Zoom, allowing the user to see points that are not visible after a zoom.

**Cross Hairs**
A cross is showed in order to target the point for which you want to read the value.

**SCENARIOS:**
Logbook entry

The Beam Loss Monitoring (BLM) operator, want to save the chart for the logbook concerning the status of the BLM systems and take a screen shoot.

1) The operator uses the two rotation slider, labeled "Elevation" and "Rotation", to rotate respectively the chart on the vertical and horizontal axis, in order to have a good visualization of all the labels on the axis before taking the screen shoot.

2) Eventually the user can Zoom using either the mouse wheel or the Slider labeled “Zoom”.

3) Using the slider, labeled "Depth Gap" the operator changes the gap between the different dataset to the 25% of the total plot depth, in order to have a better visualization of the data.

Vector Numeric data pre-analysis
Two possible situations we can have: One is when the operator needs to check whether the data exist, the second one is to check if the exist a peak in the dataset.
Data Validity Check:
When an analysis of the system is necessary on the BLM system an enormous number of data is shown this because this system is capable to take the measurements from the instrumentation every 10 nanosecond.
The operator in charge of the analysis, need to look closer to the data in order to better identify when the system behave differently.

1) After the chart is visible on the screen, the operator turns the chart on the side, using the rotation slider labeled Rotation.
2) Once the chart is on the right angle the operator change the altitude, using the slider labeled "Attitude", to find out if there is data to analyze for one of the interval time taken in consideration during the request.

Find peak in Dataset:
During the pre-analysis phase of the data one operator is in charge to analyze the vector numeric variables relative to the BLM system to check the quality of the data, in the specific to see where is the peak.
Because of the variable structure (3 Dimension) the operator need to do some interaction with the 3D chart in order to be able to check even the dataset hidden by the one before it.

1) After the chart is visible on the screen, the operator turns the chart on the side, using the rotation slider labeled "Rotation".
2) Once the chart is on the right angle he zoom using the slider labeled "Zoom" in order to find where is located the peak.
WHY JDATAVIEWER
A valid alternative to ILog could be JDataViewer for what concerns the visualization of the data in 2D.

First is enough mature and a lot of the functionalities are already present.

Second it offers more flexibility because it is homemade library. In case of necessity it is possible to develop new functionalities without dependency on third party library that require license payment.

Third doesn’t ask for the payment of licenses because it is a CERN library.

WHY JDATAVIEWER 3D EXTENSION
Although for the 2D functionalities we have a solution, however for the 3D there is a lack. JDataViewer doesn’t supply any usable 3D functionality for TIMBER.

We have decided therefore to opt for the development of an extension that could cover this lack and at the same time to keep it as a separated module by JDataViewer. In such way to leave the choice to use it to the developers, because the applications based on JDataViewer use mainly 2D functionalities.

TECHNOLOGIES CHOICE:
Among the technologies for creating 3D graphics, OpenGL is the most adopted, for its potentialities and performance but above because it is multi-platform unlike Direct3D that it is supported only by Windows platform.

It exist a java library that allows exploiting OpenGL potentialities, this library it is called Jogl (13).

JOGL offers the same functionalities described by the OpenGL specific, without giving an added value that could be used by the new extension. It means write the library from scratch.

To write a java library from scratch is not easy and take time. I have thought therefore to make a research and to use what had already been realized by others.

After some researches respecting the following criteria:
- Knowing that the JDataViewer library is written in Java, I need a library 3D that uses the same technology.
- No payment of licenses is required

Only three possible products respecting the criteria have been taken in consideration:
- Java3D (14)
- Jzy3D (15)
- Jmathplot (16)

Choice
Based on some testing on the virtual machine, where a true graphic card doesn't exist, and looking at the documentation of the three different products. I've written the following table resuming the drawback and the advantage of each library.

<table>
<thead>
<tr>
<th>Library name</th>
<th>Drawback</th>
<th>Advantages</th>
</tr>
</thead>
</table>

March 2012
Z.Makonnen  
Master Thesis  
JDVE 3D Extension

Java3D | - Not a good performance, too much high-level.  
- It is not possible to visualize the 3D objects if on a virtual machine. Because a true graphic card doesn't exist everything must be simulates via software, but not all the functionalities can be simulated.  
- It's a generic library to draw 3D object.  
- It's easy to use.

Jzy3D | - The community it's not very big.  
- Designed to plot chart  
- It uses Jogl underneath keeping a good performance.  
- It has an active community.

Jmathplot | - It doesn't use in reality OPENGL to draw the objects 3D unlike Jzy3D, but simulates it. It could reveal problematic in case a big volume of data needs to be visualizes.  
- The community it's not very big.  
- Designed to plot chart  
- It has an active community.

<table>
<thead>
<tr>
<th>Table 1-3D java library properties</th>
</tr>
</thead>
</table>

I have chosen to use as graphic library Jzy3D because it is the one that reflect more my need.

Part of the job and the functionalities they are already present because the library has been designed to draw graphic in 3D. Using this library will avoid to rewrite the main building block of the new extension.

ARCHITECTURE:
The architecture of JDVE (JDataViewer) is changed a bit as you can see. Before JDVE was a standalone library which was capable to show data in 2D. The need of showing data also on 3D has brought us to use a third part library which is an open source project. This new library which is integrated with JDVE is call Jzy3D and is using the OpenGL API to create and render 3D objects.

The 3D extension architecture has been designed on three tiers.

![Figure 25 – Architecture JDVE and 3D extension](image)
The first tier is represented by the JDataViewer library where are contained the classes that allows integration between JDataViewer and Jzy3D.

The second tier is represented by Jzy3D library where are contained the classes that allow to draw and interact with the 3D chart model.

The third tier is represented by Jogl library where are contained the classes that allow to work with the 3D engine.

DEVELOPMENT

INTEGRATION PROCESS
Since the two java libraries have a different approach to design the chart, I have done a lot of work mainly on the integration.

I had to implement some adaptors in order to avoid too much dependency between the java libraries.

Starting from JDVE the integration work has been done at different levels:

- Chart
- Renderer

Chart:
The chart designed on the 3D extension is a bit different compared with the actual one present on JDVE. Now the Chart has a new component (3D Area) in charge to manage all the 3D aspect. The two areas are mutually interchangeable.

![Chart3D structure](Image)

*Figure 26- Chart3D structure*

In green you can see the new classes.
The DefaultChart3D implement the Chart3d interface and at the same time extends the original class Chart, in order to cover at the same time the 2D and 3D functionalities.

The advantage of using this approach is that switching between 2D and 3D will not need any further modification on the library, a part for the instantiation phase.

**Renderers:**
The same approach has been used for the new 3D renderers. Because they extent the 2D already present and implement the ChartRender3D interface, the new renderers can be treated as a normal renderer without introducing big changes in the library. This means avoid rewrite new code just for the 3D renderers.

Concerning the Jzy3D library, I had to rewrite some classes to better meet my needs:

- The mouse Controller:
  - ChartMouseController3D: to control the rotation of the chart
  - ZoomMouseController3D: to control the zoom
  - ScaleMouseController3D: to control the axis scale
- The 3D View and Camera in charge of the rendering
- The 3D Axis Layout manager: to better customize the axis and labels

**Evaluation**
INTRODUCTION
To verify if the library that will go to replace ILog on TIMBER will be effective, it has been made an evaluation. During the evaluation three are the main aspects that have been taken into account:

- **Effectiveness** (The ability of users to complete tasks using the system, and the quality of the output of those tasks),
- **Efficiency** (The time necessary to perform a task)
- **Satisfaction** (users’ subjective satisfaction of the system from the point of view of usability).

The aim of the evaluation is to see how the user interacts with two 3D chart systems. In the specific, we would like to see if the user has a better result in term of performance, satisfaction and effectiveness using the new graphic library implemented at CERN (JDataViewer 3D extension) than using the old one implemented by IBM (ILog).

To do that have used a standard methodology, called within-subject design (17), where the user has to accomplish several tasks on both systems meanwhile several measures are in background.

To ensure an evaluation close to the reality where all the use cases are covered, real data has been used, with dataset containing data point ranging from 100 to 3000.

USERS
To verify that the new Java library is independently effective from the level of knowledge of the system, among the users considered for the experience, we can distinguish two types of users:

The "Expert" (Expert user): users which have already experienced the 3D functionality on TIMBER.

The "Non Expert" (Inexpert user): users which have not experienced yet the 3D functionality on TIMBER.

For my evaluation I used in total 12 people, 6 "Expert" and 6 "Non Expert" users.

USER PROFILE
The users used during the evaluation were all CERN employee with an engineer scholarship.

The population of the users had the following characteristics:

- The “Expert” average age was 37
- The “Non Expert” average age was 26
- A woman for each types of users

PROTOCOL
To better perform the Evaluation, the following protocol has been respected:

- Bring the user to the evaluation room.
- Explain to the user the motivations and the scope of the evaluation.
- Sign the agreement of participation (Appendix B) for the treatment of the data.
- Introduction with tutorial to let the user get custom with the first environment.
- Execution of the first test suite (series of task).
- Satisfaction Questioner (Appendix B).
- Tutorial to let the user get custom with the second environment.
- Execution of the second Test suite.
- Satisfaction Questioner

This protocol has been applied with every user involved, except for three people that decide to fill the Satisfaction Questioner for both systems at the end of the evaluation.

**EVALUATION ROOM**
The evaluation should be held in a room without any unnecessary objects in order to avoid any possible distraction of the user.

![Evaluation Room](image)

*Figure 29- Evaluation Room*

**TUTORIAL**
The protocol followed during the evaluation foreseen a little tutorial, for each system under test, where the user can get accustomed in order to know how to interact with the 3D world. During this session the user will learn how to use the mouse to interact directly and indirectly (using sliders), with
During the evaluation the user is free to use either the DIRECT or INDIRECT INTERACTION in order to do the following action: zoom-in, zoom-out, rotate X and rotate Y axis.

With the term "DIRECT INTERACTION", I meant the interaction that a user can do without using any artificial object (slider, button, checkbox...) to apply the action.

**Examples of mouse direct Interaction:**
When you click and drag the mouse the interaction is directly applied in the 3D world as well for the Zoom and the rotation action.

**Example of mouse indirect Interaction:**
If you position the mouse on a slider and set the Rotation angle clicking and dragging the mouse the interaction is indirectly apply in the 3D world.

The differences between the two systems that the user can feel at first are mainly the “DIRECT INTERACTIONS" that each 3D library supplies as a feature. In the APPENDIX A you can find a resume table (direct interaction table) of the action available on the systems.
TASKS:
In order to simulate the use cases we have defined a list of tasks. Each task has different objectives, number of dataset and number of points.

T1:
Task description: “Change the “DephtGap” between the different dataset to the 25%”.

Dataset number: 4; Data points: 2916;

![Figure 32 - Task 1](image1)

T2:
Task description: “Among the DATASETS there is one which has all the values at Zero. Position the camera in order to show the DATASET with this characteristic”.

Dataset number: 10; Data points: 16;

![Figure 33 - Task 2](image2)
T3:

**Task description:** “Rotate the chart on the front to better see the profile of the variable”.

**Dataset number:** 1;  **Data points:** 375;

![Figure 34 - Task 3](image)

T4:

**Task description:** “Change the point of view of the camera using the “Rotation” and “Elevation” in order to see clearly (without any superposition) all the labels on each axis”.

**Dataset number:** 18;  **Data points:** 200;

![Figure 35 - Task 4](image)
T5:

Task description: “The last DATASET it’s hidden by the one before it. Move the camera in order to see all the DATASETS”.

Dataset number: 6; Data points: 3513;

Figure 36- Task 5

AVOID BIAS:
To avoid that the bias will affect the results the within-subjects design has been used. According with a study on virtual reality by S.Livantino and C.Koffel (2008) this method will allow to overcome this problem.

Task Schedule:

<table>
<thead>
<tr>
<th>User</th>
<th>EXPERT</th>
<th>Task Schedule</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Y</td>
<td>T1 T2 T3 T4 T5 T3 T5 T4 T2 T1</td>
</tr>
<tr>
<td>2</td>
<td>Y</td>
<td>T2 T3 T4 T5 T1 T5 T4 T2 T1 T3</td>
</tr>
<tr>
<td>3</td>
<td>Y</td>
<td>T3 T4 T5 T1 T2 T4 T2 T1 T3 T5</td>
</tr>
<tr>
<td>4</td>
<td>N</td>
<td>T4 T5 T1 T2 T3 T2 T1 T3 T5 T4</td>
</tr>
<tr>
<td>5</td>
<td>N</td>
<td>T5 T1 T2 T3 T4 T1 T3 T5 T4 T2</td>
</tr>
<tr>
<td>6</td>
<td>N</td>
<td>T3 T1 T5 T2 T4 T5 T1 T4 T3 T2</td>
</tr>
<tr>
<td>7</td>
<td>N</td>
<td>T1 T2 T3 T4 T5 T3 T5 T4 T2 T1</td>
</tr>
<tr>
<td>8</td>
<td>N</td>
<td>T2 T3 T4 T5 T1 T5 T4 T2 T1 T3</td>
</tr>
</tbody>
</table>
Table 2 - Task schedule

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>T3</th>
<th>T4</th>
<th>T5</th>
<th>T1</th>
<th>T2</th>
<th>T3</th>
<th>T4</th>
<th>T2</th>
<th>T1</th>
<th>T3</th>
<th>T5</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>N</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

As you can see, from the task schedule table, for the evaluation, two groups of users had been taken in consideration, where each group is made of 3 Expert and 3 Non Expert users. Highlighted in blue are the task executed with the old 3D data visualization system.

**INDEPENDENT VARIABLES**

If we look at what are the objectives of the evaluation, which are comparing the performance and effectiveness of two different 3D data visualization systems, we can distinguish three independent variables:

- The 3D chart plotting system which has two possible values: ILOG or JDVE
- The User level which can have two possible values: “Expert” or “Non Expert”
- The task which can have five possible values: 1, 2, 3, 4 or 5

**MEASURES:**

Two measures had been taken to cover the effectiveness and efficiency aspects:

- The task interaction time
- The task accomplishment

**The task interaction time:**

This measure is used to compute the performance of the user to accomplish the task using the chart 3D.

The task interaction time include:

- The rendering time that the system, under test, need in order to compute and show the data on the screen.
- The interaction time between the user and the system, once the chart 3D is visible on screen.

**The task accomplishment:**

This measure is used to compute the task accuracy. In the specific if the task has been accomplished or not and if had require some help.

To cover the satisfaction aspect the System Usability Scale questioner had been used. Ten questions about the system usability, from a subjective global point of view. The score obtained from these questions will give us a measure in order to understand if and how the system is usable.

All the measures have been taken internally from the application, using the same machine:

- CPU Processor : Intel(R) Pentium(R) 4 CPU 3.00GHz, 3000 Mhz, 1 Core(s), 2 Logical Processor(s)
- System Model: HP Compaq dc7600 Convertible Minitower
RESULT & ANALYSIS

EFFECTIVENESS:
The Effectiveness is the accuracy and completeness with which users achieve certain goals (18). There are two ways to measure the effectiveness, either looking at the quality of solution or at the error rates. In this study, we use quality of solution as the primary indicator of effectiveness. In this specific case the Effectiveness is the capability of a user to accomplish a given task with the User Interface.

During the evaluation besides measuring the time it has been kept in consideration another factor concerning the accomplishment of the task.

To every task completed by the consumer a value was assigned between 0 and 1.

The assignment of this value is made in the following way:

- 0 if the task is not performed in the correct way
- 0.5 if the task is correctly completed with some help from the supervisor.
- 1 if the task is correctly completed without help.

From the gotten results it can be seen that the "Not Expert" have successfully completed almost all the tasks in the correct way, independently from the type of system. Among the "Expert" instead a difference is evident among the two systems.

![Effectiveness](image)

*Figure 37 - Effectiveness results*
Analyzing the data (Effectiveness-Data table in APPENDIX A); We notice that among the tasks that weren’t completed, the number 2 is the most frequent, probably due to the fact that the description of the task was ambiguous, bringing the user to a wrong interpretation.

It is possible to see from the chart below: the difference between the two systems has changed from 10 to 4 among the expert and from 5 to 2% considering all the users. However the elimination of the task 2 from the analysis didn’t change the result.

**Figure 38 - Effectiveness results without Task 2**

In conclusion we can say that the new system allows to get the desired result better that the old system.

**EFFICIENCY:**

The Efficiency is the relation between the accuracy and completeness with which users achieve certain goals and the resources expended in achieving them. Indicators of efficiency include task completion time and learning time. In this study, we use task completion time as the primary indicator of efficiency.

**SYSTEM EFFICIENCY**

After the library development I’ve done some performance comparison. Using the tasks, I took the rendering time which is the time necessary to the graphic library to show the data in a chart.

From the data we can see that the performances of the new library are quite similar compared to ILog except for the rendering of the task 4 (almost 4 seconds difference) and 5(almost 1 second).
As we said in the precedent paragraph to determine if the new system has a better performance than his predecessor, during the evaluation the time to accomplish the task has been measured.

In the table below are reported the statistics without considering the users that haven’t accomplish the task correctly (for the complete data see Efficiency-Data in the APPENDIX A).

<table>
<thead>
<tr>
<th>STATISTIC</th>
<th>Ilog (seconds)</th>
<th>JDVE (seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Task 1</td>
<td>Task 2</td>
</tr>
<tr>
<td>Mean</td>
<td>64,62</td>
<td>56,53</td>
</tr>
<tr>
<td>Median</td>
<td>49,32</td>
<td>31,09</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>36,25</td>
<td>48,38</td>
</tr>
<tr>
<td>Lower</td>
<td>28,37</td>
<td>8,15</td>
</tr>
<tr>
<td>Higher</td>
<td>100,87</td>
<td>104,91</td>
</tr>
<tr>
<td>min</td>
<td>27,77</td>
<td>14,06</td>
</tr>
<tr>
<td>max</td>
<td>143,60</td>
<td>153,85</td>
</tr>
</tbody>
</table>

Table 3- Efficiency statistics

Looking at the statistics we can see already that the average time is lower using the new 3D data visualization system.
If we observe the distribution of the data on the chart we can notice as the data is more concentrated when the average of the JDVE library gets the best results (task 1, 2, 3 and 5) compared with the other library. For the only task (task number 4) where JDVE had a less performance it can be observed that is the same that required more time for the rendering, during the system performance comparison. Therefore removing the 4 seconds (Task 4 JDVE), the difference will be 4.68 seconds instead of 8.68. It can also be observed that the distribution of the data is very big (for the tasks 4). This normally happens when the data considered have very discordant values among them.

In conclusion we can say that JDVE has a better performance than ILOG. One of the possible causes could be the fact that the actual graphic library needs, besides the calculation and rendering of the
polygons, also to compute the lights calculation. This allows having a better visualization of the chart, but requires great use of resources.

**Satisfaction:**
The satisfaction expresses the degree of satisfaction of a user with the interface.

From the System Usability Scale (SUS) questioner filled by the users we have extracted the following results that we will go to analyze.

![Satisfaction results](image)

Figure 42 - Satisfaction results

From the chart it is possible to see how the new system has better result among the "Non Expert" user.

Analyzing the data (Satisfaction-DATA table in the APPENDIX A) the questions that explain this difference, are Q3 "I thought the system was easy to use" and Q9 "I felt very confident using the system". Looking at the mean value of the two questions for each system we have that for Q3 the difference is 1.8 point (JDVE =3.3; ILOG= 1.5) and for Q9 is 1.5 point (JDVE=3.3; ILOG=1.8). This means that if a new user will start to use the new 3D data visualization system, will be easier for him to use it and he will feel more confident than the old one.

As we could aspect among the "Expert" the system JDVE doesn't get a good result but the difference it is not so great. Analyzing the data, the question Q10 "I needed to learn a lot of things before I could get going with this system" is the one that can explain this difference. This is due to the fact that the JDVE 3D extension has more functionality (8 more actions available with the mouse), allowing the user to interact with the 3D world just which requires a bit more of training, respect with the old library. Some other in reason could be probably because the users have a good confidence in the old system that has been consolidated during the past years. There is also to consider the fact that since the new 3D extension of JDVE is not yet mature, it doesn't look very nice at the eye of the users, compared with ILOG where the uses of lights allow highlighting the 3D objects.
If we consider the all users together the new system obtain the best results.

**Analysis:**
Doing an analysis of every aspects, considered during the evaluation, independently the one from the other we can say that the new system is better from the point of view of the *Effectiveness* because has gotten the best results allowing the users to complete the tasks in correct way. Even from the point of view of the *Efficiencies* where the users reached better result in term of time of task accomplishment, the new graphic library got the best results. The new 3D data visualization system is also well appreciated by most of the users even if there are few of them (among the "Expert"), that still reluctant to use it. In particular we have seen that a new user (Non Expert), without any knowledge of the old system, can perform correctly a give task on both systems (see Effectiveness). The interesting thing is that a new user is more satisfied using the new graphic library (more than 20% of difference).

**Conclusions**

**Analysis Conclusions**
The 3D library has been successfully integrated with JDVE; all the functionalities have been developed for the integration with TIMBER.

For what came out during the evaluation of *Effectiveness, Efficiencies* and *Satisfaction* we are satisfied, considering that the graphic library is still in beta version and is not performing as it should.

The system performances comparison showed that work still to be done concerning the data rendering on the 3D chart (Tasks 4 and 5).

Although the new library is not yet fully performing as it should for the rendering of the chart, this seems didn’t had a big effect on the *Efficiencies* measurements.

**Prospective**
The works done as you have been able to see it was not centered on the development of new methodology of visualization, but more I to try to reproduce the same functionalities and methods of visualization already existing. Because of this strong constraint it has not been made a comparative evaluation of the effectiveness between the classical (scatter graph, line chart, bar chart and area) techniques of visualization currently employees in TIMBER and one of the methods presented in other recent studies like "TimeWheel" or "Large Scale Time-Varying Data Visualization Method" proposed respectively by other studies C.Tominski (11) and by Maiko Imoto (12).

As next step would be interesting, to see what among these visualization techniques is the more effective. Moreover, interesting would be to understand which one is the most suitable techniques, according to the structure and the amount of data to visualize to be able to apply the most effective technique by default.

The two questions that remain open are the followings:

1) The techniques of visualization, for Time-series data, currently used by TIMBER are the most effective?

2) Which technique of visualization is the more effective according to the structure (NUMERIC or VECTOR NUMERIC) and the amount of data?
BIBLIOGRAPHY


APPENDIX A

MOUSE INTERACTIONS

<table>
<thead>
<tr>
<th>Action</th>
<th>ILog</th>
<th>JDVE</th>
<th>Slider (Indirect)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zoom-in</td>
<td>Click-LEFT + drag Forward</td>
<td>Mouse Wheel forward</td>
<td>x</td>
</tr>
<tr>
<td>Zoom-out</td>
<td>Click-LEFT + drag Backward</td>
<td>Mouse Wheel Backward</td>
<td>x</td>
</tr>
<tr>
<td>X-Rotation</td>
<td>Click-RIGHT + drag Left/Right</td>
<td>Click-LEFT + drag Left/Right</td>
<td>x</td>
</tr>
<tr>
<td>Y-Rotation</td>
<td>Click- RIGHT + drag Forward/Backward</td>
<td>Click-LEFT + drag Forward/Backward</td>
<td>x</td>
</tr>
<tr>
<td>Depth</td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Gap</td>
<td></td>
<td></td>
<td>x</td>
</tr>
</tbody>
</table>

Table 4 - DIRECT/INDIRECT interaction

In the table above you have a resume of the actions supplied by the libraries.

EFFECTIVENESS-DATA

<table>
<thead>
<tr>
<th>Task id</th>
<th>ILOG (accomplished = 1 ; with help= 1/2 ; not accomplished = 0)</th>
<th>JDVE (accomplished = 1 ; with help= 1/2 ; not accomplished = 0)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>User 1</td>
<td>User 2</td>
</tr>
<tr>
<td>1</td>
<td>1,0</td>
<td>1,0</td>
</tr>
<tr>
<td>2</td>
<td>1,0</td>
<td>1,0</td>
</tr>
<tr>
<td>3</td>
<td>1,0</td>
<td>1,0</td>
</tr>
<tr>
<td>4</td>
<td>1,0</td>
<td>1,0</td>
</tr>
<tr>
<td>5</td>
<td>1,0</td>
<td>1,0</td>
</tr>
<tr>
<td>subtotal</td>
<td>5,0</td>
<td>5,0</td>
</tr>
<tr>
<td>Total %</td>
<td>96,67%</td>
<td>88,33%</td>
</tr>
</tbody>
</table>

Table 5 - ILOG Effectiveness

<table>
<thead>
<tr>
<th>Task id</th>
<th>JDVE (accomplished = 1 ; with help= 1/2 ; not accomplished = 0)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>User 1</td>
</tr>
<tr>
<td>1</td>
<td>52,56</td>
</tr>
<tr>
<td>2</td>
<td>139,67</td>
</tr>
<tr>
<td>3</td>
<td>28,84</td>
</tr>
<tr>
<td>4</td>
<td>60,81</td>
</tr>
<tr>
<td>5</td>
<td>136,53</td>
</tr>
<tr>
<td>subtotal</td>
<td>5,0</td>
</tr>
<tr>
<td>Total %</td>
<td>96,67%</td>
</tr>
</tbody>
</table>

Table 6 - JDVE Effectiveness

EFFICIENCY-DATA

<table>
<thead>
<tr>
<th>Task id</th>
<th>ILOG Time(second)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Non Expert</td>
</tr>
<tr>
<td></td>
<td>User 1</td>
</tr>
<tr>
<td>1</td>
<td>52,56</td>
</tr>
<tr>
<td>2</td>
<td>139,67</td>
</tr>
<tr>
<td>3</td>
<td>28,84</td>
</tr>
<tr>
<td>4</td>
<td>60,81</td>
</tr>
<tr>
<td>5</td>
<td>136,53</td>
</tr>
<tr>
<td>subtotal</td>
<td>5,0</td>
</tr>
<tr>
<td>Total %</td>
<td>96,67%</td>
</tr>
</tbody>
</table>

Table 7 - Tasks execution time with ILOG

March 2012
Z. Makonnen

Master Thesis

JDVE 3D Extension

<table>
<thead>
<tr>
<th>Task id</th>
<th>JDVE Time(second)</th>
<th>Expert</th>
<th>Non Expert</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>User 1</td>
<td>User 2</td>
<td>User 3</td>
</tr>
<tr>
<td>1</td>
<td>90.88</td>
<td>58.76</td>
<td>68.19</td>
</tr>
<tr>
<td>2</td>
<td>17.98</td>
<td>72.63</td>
<td>3.64</td>
</tr>
<tr>
<td>3</td>
<td>28.54</td>
<td>18.05</td>
<td>12.22</td>
</tr>
<tr>
<td>4</td>
<td>29.81</td>
<td>110.54</td>
<td>44.05</td>
</tr>
<tr>
<td>5</td>
<td>33.31</td>
<td>32.07</td>
<td>18.42</td>
</tr>
</tbody>
</table>

Table 8 - Task execution time with JDVE

SATISFACTION - DATA

<table>
<thead>
<tr>
<th>Question</th>
<th>Non Expert SUS Result</th>
<th>Expert SUS Result</th>
<th>ILOG</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>JDVE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>User</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Q 1</td>
<td>4</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>Q 2</td>
<td>3</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Q 3</td>
<td>4</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Q 4</td>
<td>4</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Q 5</td>
<td>4</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Q 6</td>
<td>4</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Q 7</td>
<td>4</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Q 8</td>
<td>4</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Q 9</td>
<td>4</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Q 10</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Sub-Total</td>
<td>92.5</td>
<td>42.5</td>
<td>92.5</td>
</tr>
<tr>
<td>Total SUS Result</td>
<td>82.92</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 9 - SUS Non Expert Questioner results

<table>
<thead>
<tr>
<th>Question</th>
<th>Expert SUS Result</th>
<th>ILOG</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>JDVE</td>
<td></td>
</tr>
<tr>
<td>User</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Q 1</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Q 2</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Q 3</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Q 4</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Q 5</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Q 6</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Q 7</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Q 8</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Q 9</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Q 10</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Sub-Total</td>
<td>77.5</td>
<td>37.5</td>
</tr>
<tr>
<td>Total SUS Result</td>
<td>73.75</td>
<td></td>
</tr>
</tbody>
</table>

Table 10- SUS Expert Questioner results

March 2012
APPENDIX B

Participant Consent Form

Project Title: JDataViewer 3D Extension
Researcher: Makonnen Zereyakob
Supervisors: Prof. Gilles Falquet (CUI/UNIGE)

- I have received information about this research project.
- I understand the purpose of this research and my involvement in it.
- I understand that I may withdraw from the research project at any stage.
- I understand that while information gained during the study may be published, I will not be identified and my personal results will remain confidential.

I agree with the terms above and indicate my agreement by signing here:

Name of participant: .................................................................

Signature: .............................................................................

Date: .....................................................................................
System Usability Scale


1. I think that I would like to use this system frequently

2. I found the system unnecessarily complex

3. I thought the system was easy to use

4. I think that I would need the support of a technical person to be able to use this system

5. I found the various functions in this system were well integrated

6. I thought there was too much inconsistency in this system

7. I would imagine that most people would learn to use this system very quickly

8. I found the system very cumbersome to use

9. I felt very confident using the system

10. I needed to learn a lot of things before I could get going with this system
<table>
<thead>
<tr>
<th>Task</th>
<th>Accomplished</th>
<th>Accomplished with help</th>
<th>Not Accomplished</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1st System</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>2nd System</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 11 – Evaluation Table