Visualization of Statistical Contents

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Abstract
Our project presents the research on visualization of statistical contents. Here we will introduce the concepts of visualization, software quality metrics and proposed visualization technique (line chart). Our aim to study the existing visualization techniques for visualization of software metrics and then proposed the visualization approach that is more time efficient and easy to perceive by viewer.

In this project, we focus on the practical aspects of visualization of multiple projects with respect to the versions and metrics. This project also gives an implementation of proposed visualization techniques of software metrics. In this research based work, we have to compare practically the proposed visualization approaches. We will discuss the software development life cycle of our proposed visualization system, and we will also describe the complete software implementation of implemented software.

Keywords: Software Visualization, Software Metrics, Charts (line chart), Statistical Contents, Quality Metrics.
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1. Introduction
Systems can contain a big amount of software entities that allows users to visually analyze, explore and compare a statistical data of different projects. Software visualization tools are used by software designers to raise the level of abstraction and reduce the amount of information to the one needed. Mostly these are different projects versions, data can be import and export which force the user to switch between different windows and contexts. The development of software visualization frameworks is a significant step to bring visualization tools in the forward engineering process [1], [2] and [3].

1.1. Problem Description
Bulk amount of data is produced due to the rapid advances in computer technology. Mainly, the data comes from statistical data gathering, automated measurements and simulations, and this will become the primary source for a large dataset, which contains a large number of items, variables and time steps. It is very difficult to display a huge number of attributes in a small graphical representation. Our target is to design visualization application that is useful to display as much as possible software metrics within small drawing canvas with high quality display and time efficiency.

In our work, we have to visualize the statistical contents using proposed technique, which contains either too many data objects or attributes for a visualization to be efficiently carried out using a propose techniques, is referred to as being large. Depending on the application area, efficient can have different meanings. In general, representations that enable efficient information visualization are those which convey information about data in a clear and interpretable way, and in a reasonable time. Therefore, we need to develop an effective (time efficient, low memory consumption, accuracy) approach to visualize software metrics for a large statistical content. We will try to prove the efficiency of our proposed application in test scenarios, experiments and conclusion, describing in later chapters.

1.2. Goals
This project presents a technique that allows viewers to visually analyze, explore, and compare a statistical data of different projects. We present an algorithm that visualizes data along 2D-Charts. We use simple graphical objects that vary in color and placement properties to represent the attribute values contained in a data element. When shown together, the glyphs form visual patterns that support exploration, facilitate discovery of data characteristics, and highlight trends and exceptions.
1.3. Objectives
In the following we identify some important objectives for our research:

- Design graphical representation of statistical contents using 2D-Graphics.
- To implement a visualization technique that is more user friendly and time efficient for a large dataset.
- Develop a Database-Interface that provides the communication between online Visualization-Tool and Database.
- Construct the new dataset by computing the average values of all attributes of each project.
- Develop the Web-Based visualization tool on client-side.
- Develop the server-side tool to upload the metrics data of projects along their version information into database.

Our primary objective in this project is to design a graphical glyph that supports flexibility in its placement and in its ability to represent statistical data objects. We focus to accommodate a high number of attributes by a small graphical representation.

The main part of this project is to develop a software tool that can accept any type of multivariate raw data, compute statistically and represent it graphically. Our software is able to read the dataset from some external data source; it can be some file system.

1.4. Background
The background of our research includes a brief explanation of software visualization, software metrics and measuring the statistical contents and also why we use visualization in computer science and other fields.

1.4.1. Software Visualization
Software Visualization either static or dynamic (animated) 2D or 3D is used to visual representations of information about software systems based on their structure, size, or behavior. The information used for visualization is software metric data from measurement activities differently with different behaviors. The actual objectives of software visualizations are to support the understanding of software systems (i.e., its structure) and algorithms (e.g., by animating the behavior of sorting algorithms) [4] as well as the analysis of software systems and their anomalies (e.g., by showing classes with height coupling) [7], [5], [6].

Software Visualization uses graphical representation to show code, control flows, classes, data, objects and dependencies among them. Therefore the programmer and software designer would have software visualization instead of lines of code displayed in a textual editor [3].

1.4.2. Software Metrics
Software metric is standard of measurement. Software metric computes property of a piece of software or its specifications. Since quantitative methods have been proved so powerful in other sciences, computer science practitioners and
theoreticians have worked hard to bring similar approaches to software development. Tom DeMarco stated, “You can’t control what you can’t measure”. There are countless examples of software metrics: like lines of code, cyclomatic complexity, function point analysis, bugs per line of code, code coverage, number of lines of customer requirements, number of classes and interfaces, Robert Cecil Martin’s software package metrics cohesion or coupling [8]. Management methodologies, such as the Capability Maturity Model or ISO 9000, have therefore focused more on process metrics which assist in monitoring and controlling the processes that produce the software [8].

1.4.3. Why Visualization Can Help
Visualization is an area that presents data in a visual form to facilitate rapid, effective, and meaningful analysis and interpretation. Example application domains include scientific simulations, land and satellite weather information, geographic information systems, and molecular biology [10]. Visualization is also used in more abstract settings, for example, software engineering, data mining, and network security. A key challenge is designing visualizations that are effective for the user’s data and analysis tasks [9].

The Software Visualization approach constructs visual representations that harness the strengths of the low-level human visual system. These perceptual visualizations display the data in ways that allow items of interest to capture the user’s focus of attention [10].

It is a very critical situation to analyze the large size of the average dataset. The desire to extract knowledge efficiently motivates the need for an effective visualization system. A dataset’s size is made up of three related properties:
- Number of elements stored in the dataset
- Number of attributes represented within the dataset
- Range of values possible for each attribute

Visualization tools are used to visualize these properties with effective representation (easy to perceive by viewer). These properties are represented in visualization known as information content and it is a combination of following properties:
- Number of elements
- Number of attribute values per element
- Range of different attribute values being visualized

The new technique described in this project seeks to increase information content by focusing on the last two properties, dimensionality and range [11].

1.4.4. Statistical Contents
In this thesis, we have projects with different versions, like Table 1.1 shows different classes and their metrics like LOC, WMC, TCC, NAM, NOM, MPC, LOD and different values against each Class, similarly Table 1.2, Table 1.3 shows the same project but as an improved version of the project.
1.5. Outline

Chapter 2 is about research work already done related to visualization of statistical contents of software projects. Chapter 3 contains the research and development methodology has been used in this project and analysis and design of the proposed system which also includes function and nonfunctional requirements, use case diagram of our visualization system. It also includes the test cases and database design of our application. In Chapter 4, we describe our implemented visualization techniques. It contains detailed overview of our software interaction and utilities too. Chapter 5 is complete explanation of our software implementation. Chapter 6 contains some case studies related to our research. Chapter 7 describes our conclusion and future work related to this research work.
2. Visualization and Proposed Techniques
This chapter includes some relevant research and literature covering the different visualization techniques in general. We also used a book of Colin Ware [12] that covers the many topics of information visualization (texture, glyph, animation).

2.1. Related Work
We will discuss previous work in short that is directly related to our proposed techniques, and highlight areas where we may possibly able to offer improvements over existing methods.

2.1.1. Charts
Charts are used to visually represent data, in which data is represented by symbols such as bar chart or line in a line chart [13]. A chart can represent tabular numeric data, functions or some type of quantitative structures [14]. The term “chart” has multiple meanings.

- Data chart is a type of diagram or graph that organizes a set of numerical data.
- Maps that are adorned with extra information (nautical chart or aeronautical chart) for a specific purpose is also known as charts.
- Music notation chart or record charts for album popularity, which are domain specific, are also known as charts.

Charts are used to ease understanding of large quantity of data and representing the relationship between those data. Charts can be read and understandable more than raw data. Charts are used in wide variety of application either they are design by hand or through computer applications.

Feature of Charts
Chart covers a large variety of forms. Some common features of charts having ability to extract meaning from data. A chart is a graphical, containing very little text like displaying values, title and description about the axis data [14].

Dimensions in the data are often displayed on axes. Horizontal and vertical axis are commonly used and are referred to as the X-axis and Y-axis respectively which are scale properly in intervals and also accompanied some suitable labels describing the dimension represented [13].

In charts grid can be used to align data into lines and is enhance able to a regular graduations. Chart data can be appear in different manner, it can be visualize without any proper labels displaying the contents, It may appear in dots or other shape, different patterns, colors, connected or unconnected line [14].

Data appearing in a chart contains multiple data sets, which visualize the difference and association among them [14].
Types of Charts

Most common types of charts are as follows
- **Histogram**: Shows the quantity of point falls within numeric ranges
- **Pie Chart**: Shows percentage values as a slice
- **Bar Chart**: Show values for different categories
- **Line Chart**: A two dimensional scatter plot of ordered observations

Less common types of charts are as follows
- **Bubble chart**: Two dimensional scatter plot where point size the represent the third value
- **Polar Area Diagram**: An enhanced form of pie
- **Radar Chart**: Three or more quantitative variables represented on axes starting from the same point
- **Water fall Chart**: Special type of floating-column chart
- **Candlestick Chart**: It is also a type of bar chart which describes the movements of prices over time
- **Kagi Chart**: Time independent stock tracking chart
- **Spakline Chart**: This kind of chart is used, where less detail required and chart size is paramount [14]

2.1.2. **Glyphs**
A Glyph is a graphical unit used to visualize the data of any type. It is a graphical symbol that provides appearance to data or form a shape for an existing data. A glyph may have properties of orientation, scaling, translation, deformation, size, placement, and color, etc. These properties are used to represents the input data. Glyphs are prejudiced by attributes of the current dataset. Different glyphs based visualization techniques are discussed here.

Chernoff developed iconic representation of the human face [15], [16]. The face elements like nose, eyes, eyebrows, mouth, and jowls are changed according to input data values. Foley and Ribarsky have created a visualization tool called ***Glyphmaker*** that is used to create visualization of multivariate datasets [17]. This tool uses a glyph editor and a glyph binder to create glyphs, to arrange them spatially, and to bind attributes to their visual properties. Levkowitz represented a visualization of colored squares to produce patterns to represent multivariate datasets [18].

In our thesis we find Glyphs are most suitable to visualize software metrics. Where they used to improve the visualization for a larger dataset, for example, scaling shows the attribute strength, or coloring to identify attribute or objects.

2.1.3. **Java Open Source Charting Tools**
In this thesis, we explore different charting and reporting tools in Java and few of them are mention below, which facilitate different visualization techniques and there features [30].
**JFreeChart**

It is a free Java class library used to generate chart like Pie Charts (2D and 3D), bar charts (regular and stacked, with an optional 3D effect), line and area charts, scatter plots and bubble charts, time series, high/low/open/close charts and candle stick charts, combination charts, pareto charts, gantt charts, wind plots, meter charts and symbol charts, wafer map charts [30], [31].

**Prefuse**

Java based toolkit to build interactive information visualization application. It supports different set of features for data modeling, visualization, and interaction. It provides optimized data structures for tables, graphs, and trees, a host of layout and visual encoding techniques, and support for animation, dynamic queries, integrated search, and database connectivity [30], [31].

**JOpenChart**

It is an open source Java library and toolkit for creating different kinds of charts and embedding them into web applications or Swing applications. [30]

**Chart2D**

Chart2D is a library written in Java for adding 2D charts to Java programs [30].

**JChart2D**

A Java Swing Widget (JComponent) for precise runtime dynamic display tupels in form of a stripe chart. Key future of JChart2D is minimal configuration effort, automatic scaling and labeling, thread safeness, a clean and extendible API and extensive documentation [30].

**2.2. Visualization Approaches**

In our research work, our visualization approach based over the user requirements and to meet the requirements we have studied few existing software visualization techniques to display a multivariate dataset. We found some of existing visualization tools that have been used as a different type of visualization features like, texture, animation, charts and flow visualization in 2D or 3D environment [23] [24].

**2.2.1. Line Charts**

Line graph or chart is created by connecting a series of data points together with a line. Line graph or charts are a great choice and commonly used for data visualization. A line chart is often used to visualize a trend in data over intervals of time [22]. It is easy to understand and is great way to compare different data series which are change able with time. Especially it is a nice when comparing two or more datasets. Different options are available in line chart or graph to display/setting up information, we can set them up at x-axis and y-axis relate to version or values [20] [21] [22].
2.2.2. 2D Environment
We analyzed 3D visualization [25], [26] that is more complex and expensive to render the resulting image or display. We therefore concluded to use 2D (Two Dimensional) environment for the visualization tool to display software statistical contents.

2.2.3. Proposed Line Chart Visualization
After analysis and discussion of different related topics, we consider the following computational and visualization approach in this project.

![Proposed Visualization: Chart Visualization](image)

*Figure 2.1. Proposed Visualization: Chart Visualization*

In the graphical representation, shown in Figure 2.1, we have a 2D-Chart that contains a number of Poly Lines with Circle Objects. Where, each Line is drawn with help of different metric values, and it represents with unique Color (where, Color of line represents a single Project), and each Circle object identifies the single Software Metric.

2.3. Summary
In this chapter, we studied and discuss different visualization techniques by different researchers and their opinions about different techniques. After comprehensive research of software visualization, we reached at a point where we are able to finalize our proposed techniques (Section 2.2.3) for visualization of statistical contents. Our next step is to analyze the requirements of proposed system and then we will design the proposed visualization tool.
3. Requirement Analysis and Design

In this chapter, we will discuss and describe the development methodology and requirements of our proposed system and interaction between user and system, using UML diagrams.

3.1. Methodology

This section includes software development methodology which we have used in our research work. After considering the nature of our project and goal we have to attain, we chose Iterative and Incremental Development Methodology to develop our software.

3.1.1. Iterative and Incremental Process Model

In an iterative and incremental lifecycle (Figure 3.1), is a rework strategy in which various part of the system is revised and improved at different rates, with the intention for software project to understand the system it is building [29]. Iterative development is a rework scheduling strategy in which time is set aside to revise and improve parts of the system. It does not assume incremental development, but it works well with it. The basic idea behind iterative enhancement is to develop a software system incrementally, allowing the developer to take advantage of what was being learned during the development of earlier, incremental, deliverable versions of the system.

![Figure 3.1. System Development Life cycle [28]](image)

The Rational Objectory Process defines the control for an iterative and incremental lifecycle. It defines an extensive set of guidelines that address the technical aspects of software development focusing on requirements analysis and design [30].

“Objectory is an iterative process. Given today’s sophisticated software systems, it is not possible to sequentially first define the entire problem, design the entire solution, build the software and then test the product at the end. An
iterative approach is required that allows an increasing understanding of the problem through successive refinements, and to incrementally grow an effective solution over multiple iterations. An iterative approach gives better flexibility in accommodating new requirements or tactical changes in business objectives, and allows the project to identify and resolve risks earlier” [30].

This process is structured along two dimensions:
- time and,
- process

**The Time dimension is structured as follow:**
- **Inception:** It is a specification of the project vision. In this phase, we have to focus on the actual problem, requirements gathering, and research work.
- **Elaboration:** Planning the necessary activities and required resources; specifying the features and designing the architecture.
- **Construction:** Building the product as a series of incremental iterations.
- **Transition:** Supplying the product to the user community (manufacturing, delivering, and training).

**The Process dimension includes the following activities:**
- **Project Management:** It includes planning of project development, development cases, description and guidelines.
- **Requirements:** Requirement specification of proposed system.
- **Analysis & design:** Analyze and describe the main functionalities of the proposed system, and also design the system for implementation phase.
- **Implementation:** Code generation and programming that will result in an executable system.
- **Test:** Verification of the entire system.
- **Deployment:** Deliver to end user in an operating environment.

Each activity of the process component dimension is applied to the each phase of the time based dimension. *Figure 3.2* shows how the process components are applied to each time based phase [28], [29], [30].
As we described the life cycle and the Rational Objectory Process of the Iterative and Incremental process model, we used the same development methodology in our research project. Similar to the proposed model, we

- get the requirements at first,
- analyze the old visualization research of software metrics,
- design the architecture of proposed system,
- develop the code, and
- test the entire program

All above steps are described in this report in detail. In the next section, we will define the requirement specification and use cases, which help us further to design the proposed system [30].

### 3.2. Requirements

Requirements analysis is the first stage in the systems engineering process and software development process [33]. A requirement specification helps us to define the scope and boundaries of the proposed system which leads to a better understanding of overall system. Two types of requirements: functional requirements and non-functional requirements.

#### 3.2.1. Functional Requirements

Now, we are having a view over the functional requirements of proposed system. It defines the main functions or components of a software system, and each of them includes the required function of the proposed system, its importance, and a brief description.
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<tr>
<td>Description</td>
<td>Enter information which kind of analysis tool, its version and type of analyze like class level, method level and package level.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>FR-06</th>
<th>Display Chart</th>
</tr>
</thead>
<tbody>
<tr>
<td>Importance</td>
<td>Desirable</td>
</tr>
<tr>
<td>Description</td>
<td>To visualize software metrics and projects in charts.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>FR-07</th>
<th>Zoom</th>
</tr>
</thead>
<tbody>
<tr>
<td>Importance</td>
<td>Desirable</td>
</tr>
<tr>
<td>Description</td>
<td>Zoom in or Zoom out to view clearly all metrics and projects more clearly.</td>
</tr>
<tr>
<td>-------------</td>
<td>---------------------------------------------------------------------</td>
</tr>
<tr>
<td>FR-08</td>
<td>Print Drawing</td>
</tr>
<tr>
<td>Importance</td>
<td>Desirable</td>
</tr>
<tr>
<td>Description</td>
<td>Printing drawing on paper, Print Drawing button allows printing through printers.</td>
</tr>
<tr>
<td>FR-9</td>
<td>Export Drawing Image</td>
</tr>
<tr>
<td>Importance</td>
<td>Desirable</td>
</tr>
<tr>
<td>Description</td>
<td>Save drawing as an image file, for later use.</td>
</tr>
<tr>
<td>FR-10</td>
<td>Download Drawing Data</td>
</tr>
<tr>
<td>Importance</td>
<td>Desirable</td>
</tr>
<tr>
<td>Description</td>
<td>Download drawing data (metrics) in a text file.</td>
</tr>
<tr>
<td>FR-11</td>
<td>Mouse Over On Data Points Display Metric</td>
</tr>
<tr>
<td>Importance</td>
<td>Desirable</td>
</tr>
<tr>
<td>Description</td>
<td>On mouse over data points it display project, its version and metric information</td>
</tr>
</tbody>
</table>

Table 3.1. Functional requirements

3.2.2. Non-Functional Requirements
In this section, we will describe and discuss non-functional requirements with their importance and brief description, which also describe as usability, reliability, performance, and substitutability requirements.

<table>
<thead>
<tr>
<th>N-FR-01</th>
<th>Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Importance</td>
<td>Essential</td>
</tr>
<tr>
<td>Description</td>
<td>The system should work fast.</td>
</tr>
<tr>
<td>N-FR-02</td>
<td>Efficient Display of Statistical Contents</td>
</tr>
<tr>
<td>---------</td>
<td>------------------------------------------</td>
</tr>
<tr>
<td>Importance</td>
<td>Essential</td>
</tr>
<tr>
<td>Description</td>
<td>To compare and manipulate the metric values in currently displaying data objects.</td>
</tr>
<tr>
<td>N-FR-03</td>
<td>Efficient Data structure</td>
</tr>
<tr>
<td>Importance</td>
<td>Essential</td>
</tr>
<tr>
<td>Description</td>
<td>Data structure must be efficient to get fast results.</td>
</tr>
<tr>
<td>N-FR-04</td>
<td>Application Maintenance</td>
</tr>
<tr>
<td>Importance</td>
<td>Essential</td>
</tr>
<tr>
<td>Description</td>
<td>Application can be maintainable, well documented.</td>
</tr>
<tr>
<td>N-FR-05</td>
<td>Application Scalability</td>
</tr>
<tr>
<td>Importance</td>
<td>Desirable</td>
</tr>
<tr>
<td>Description</td>
<td>The system should be scalable. It should be helpful for developers to add the new features and functionalities.</td>
</tr>
<tr>
<td>N-FR-06</td>
<td>Platform Independent</td>
</tr>
<tr>
<td>Importance</td>
<td>Desirable</td>
</tr>
<tr>
<td>Description</td>
<td>The system should work on all computer machines.</td>
</tr>
</tbody>
</table>

*Table 3.2. Non-Functional requirements*
3.2.3. **Use Case Diagram**

![Use Case Diagram](image)

*Figure 3.3. Use Case Diagram*

3.3. **Test Cases**

In this section, we will discuss about our test scenario, how the contents can be visualize in a useful way? We are displaying metrics values in charts, where X-axis displays the Scaled Project Versions and Y-axis displays Scaled Metric values, where circles with different colors displays metric with respect to version. Our System allows to draw conclusions about software application related standards, conventions, and regulations in laws and similar prescription. Metrics are classified as supporting mainly statements on,

- Software Complexity,
- Software Architecture and Structure, and
- Software Design and Coding.
3.3.1. Software Complexity
Complexity metrics refer to the static, i.e., structural size and complexity of software. Complexity of software entities can be assessing by the following properties.

- Size
- Interface Complexity
- Structural Complexity

Here, we can analyze the complexity of given software entity through,

**LOC (Size):**
LOC is used to count the line of source code. LOC is a powerful software metrics entity to compute / assess the complexity of software entities. It is an important measure; “More lines of code mean more bugs” debugging is the most expensive and time-consuming part of the software development. Here one can assess complexity with respect to size.

![Figure 3.4. Test Case: Visualizing complexity of different projects by LOC](image)

As shown in Figure 3.4, displaying LOC in a chart by using software metric LOC, used to compute the complexity of software entities by their versions orders. Three software project (*Jedit, PMD, Xerces2*) having about 50 versions are shown in Figure 3.4, where the trend of line to upwards displays the increasing size of the source code (Complex) for the corresponding version and trend to tend to down displays the decreasing size of the source code.
Analysis by Visualizing the Size Complexity of given Projects
User can access and analyze the common software qualities through our system, which ensure the different characteristics of Maintainability, Re-Usability, reliability, and efficiency of a software system. Here, we will describe our analysis of three projects PMD, JEdit and Xerces2 of Figure 3.4.

- **Functionality:** User can assess the functionality of the projects with respect to their versions as PMD is having less functionality than other projects and also different versions have higher and lower functionality. “Might increase with increasing LOC”.

- **Reliability:** displays three projects PMD, JEdit and Xerces2, User can analyze the reliability of the projects with respect to their versions as PMD might be less reliable than other projects and also different versions might be higher and lower reliability. “Might increase with increasing LOC”.

- **Re-Usability:** User can analyze the re-usability of the projects with respect to their versions as PMD might be highly re-usable than other projects and also different versions might be higher and lower re-usability. “Might decrease with increasing LOC”.

- **Efficiency:** User can analyze the efficiency of the projects with respect to their versions as PMD is highly efficient than other projects and also different versions might be higher and lower efficiency. “Decline with increasing LOC”.

- **Maintainability:** User can analyze the maintainability of the projects with respect to their versions as PMD is highly maintainable than other projects and also different versions might be higher and lower maintainability. “Decline with increasing LOC”.

- **Portability:** User can analyze the portability of the projects with respect to their versions as PMD is highly portable than other projects and also different versions might be higher and lower portability. “Decline with increasing LOC”.
**NOM (Interface Complexity):**
We can compute interface complexity through NOM. Number of local Methods measures the number of methods locally declared in a class, where inherited methods are not included. It is the size of the interface of a class and allows conclusions on its complexity.

Figure 3.5. Test Case: Visualizing complexity of different projects by NOM

The above properties well describes the results asses from the Figure 3.5.

**Analysis by Visualizing the Interface Complexity of given Projects**
- **Functionality:** jEdit and PMD are less functional then Xerces2.
- **Reliability:** jEdit and PMD are less reliable then Xerces2.
- **Efficiency:** jEdit and PMD are more efficient then Xerces2.
- **Maintainability:** jEdit and PMD are easy to maintain then Xerces2.
WMC (Structure Complexity):
Assessing Structure complexity using Weighted Method Count (WMC), WMC is the sum of the McCabe's Cyclomatic Complexity values of all methods in the package.

Figure 3.6. Test Case: Visualizing complexity of different projects by WMC

Analysis by Visualizing the Structural Complexity of given Projects
Above properties defines the system behavior about the structure complexity.

- **Functionality:** Xerces2 is more functional than the jEdit and PMD
- **Reliability:** Xerces2 is more reliable than the jEdit and PMD
- **Efficiency:** Xerces2 is less efficient than the jEdit and PMD
- **Maintainability:** Xerces2 is difficult to maintain than the jEdit and PMD
3.3.2. Architecture and Structure:
- Inheritance
- Coupling
- Cohesion

**DIT (Inheritance):**
Depth of Inheritance Tree measures how many super classes can affect a class, which is applicable in Object Oriented Systems. It is said that classes with big depth of inheritance tree (DIT) metric are difficult to understand and to maintain.

*Figure 3.7. Test Case: Visualizing structural analysis of projects by DIT*

As shown in Figure 3.7, Displaying DIT in a chart by using software metric DIT, used to compute the complexity of software entities by their versions orders. Four software project (*Jedit, PMD, Xerces2 and tomcat*) having about 50 versions are shown in Figure 3.7.

**Analysis by Visualizing the Inheritance Architecture of given Projects**
Above given properties well define the inheritance.

- **Functionality:** Large number of Xerces2 versions are more functional the other software projects.
- **Reliability:** As we can see in Figure 3.7, project Xerces2 is more fault tolerance and recoverable then other projects but maturity level of Xerces2 is less then other projects.
- **Efficiency:** Xerces2 is less efficient then other software projects.
• **Maintainability:** Xerces2 is difficult to maintain then other Software projects in the figure.

**CBO (Coupling):**
Coupling between Objects is the number of other classes that a class is coupled to. CBO is only applicable to object-oriented systems.

![Figure 3.8. Test Case: Visualizing architectural analysis by CBO](image)

**Analysis by Visualizing the Coupling Architecture of given Projects**
Above given properties are well define the coupling.

- **Functionality:** As we can see in Figure 3.8, project jEdit operate-ability is lesser but security is higher.
- **Reliability:** jEdit is reliable then other project in the figure.
- **Re-Usability:** jEdit is easy to re-usable then other project in the figure.
- **Efficiency:** jEdit is more efficient then other project in the figure.
- **Maintainability:** jEdit is easy to maintain then other project in the figure.
**LCOM (Cohesion):**
The Lack of Cohesion in Methods metric is a measure for the number of not connected method pairs in a class representing independent parts having no cohesion. It represents the difference between the number of method pairs not having instance variables in common, and the number of method pairs having common instance variables.

![Diagram showing the analysis of architectural analysis by LCOM](image)

**Figure 3.9. Test Case: Visualizing architectural analysis by LCOM**

**Analysis by Visualizing the Cohesion Architecture of given Projects**
- **Re-Usability:** PMD project some version are more re-usable then other project versions, from scaled project version 2 they are less re-usable then other projects due to increase of LCOM.
- **Efficiency:** PMD project some version are more efficient then other project versions, from scaled project version 2 they are less efficient then other projects due to increase of LCOM.
- **Portability:** In PMD project, some versions are more portable then other project versions, from scaled project version ‘2’ they are discourage portability then other projects due to increase of LCOM.
3.3.3. Design Guidelines

**LOD:**
How many comments are lacking in a class, considering one class comment and a comment per method as optimum. Structure and content of the comments are ignored.

![Figure 3.10. Test Case: Visualizing architectural analysis by LOD](image)

**Analysis by Visualizing the Design Guideline of given Projects**
*Figure 3.10*, present better assessment of Design guidelines of software projects.
- **Reliability:** Xerces2 is more reliable than other projects in figure.
- **Re-usability:** Xerces2 is more suitable to re-use then other projects.
- **Maintainability:** Xerces2 is easy to maintain then other projects in figure.

3.4. Database Schema
Tables below shows the database schema used for the raw data after information extraction. We have seven tables and our system supports to add more tables according for different type metrics. In this section we will describe and discuss our database schema, which describe relation, attribute, data type of attributes and association between relations. I will discuss database schema into two different parts Tij and Sij.
Database Name: *statistics*

Table: tabanalysistools

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<tr>
<th>Name</th>
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*Table 3.3. Table tabanalysistools Fields*

Table: tabanalysistoolversions

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<th>Comment</th>
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*Table 3.4. Table tabanalysistoolversions Fields*

Table: tabanalysistype

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*Table 3.5. Table tabanalysistype Fields*

Table: tabmetrics

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</tbody>
</table>

*Table 3.6. Table tabmetrics Fields*

Table 3.3 to 3.10 displays the different tables belong to tool and keep raw data of a tool and analysis type. Tij, with i tool and j version are stored in table
tabanalysistoolversion. Tij (Mm,An), with metric are stored in a table tabmetrics. Table typeanslysitetype store information which type of analysis either class, method level or other and in Table tabmetrics it defines the software quality model supports a list of metrics {LOC,WMC,TCC….WMC} or some different metrics. Database is more general and supportive to include a new Software quality model.

**Table: tabclasses**

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**Table 3.7. Table tabclasses Fields**

**Table: tabprojects**

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Table 3.8. Table tabprojects Fields

Table: tabprojects

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Table 3.9. Table tabprojectversions Fields

Table 3.11 to 3.16 displays the different tables belongs to System and keep raw data of a system. $S_{ij}$, with $i$ System and $j$ version are stored in table tabprojectversion. The version string is not always sufficient to bring the systems into a correct timely order; therefore we have an additional integer attribute versionorder.

Table tabclasses contains separate analysis one or more datasets for every class $C_{i,j,k}$ of a system. The attributes correspond to the absolute metrics values $M_l(C_{i,j,k})$ extracted for the metrics $l \in \{\text{Maintainability, LOC, \ldots, WMC}\}$ as defined in software quality model.

3.5. Summary
In this Chapter, we defined the functional and nonfunctional requirements which help us to design the use cases and also database. We included database information and its design as well.
4. Implementation
In this chapter, we will discuss about our implementation aspects, tools, major components and environment in which codes are written.

4.1. Eclipse Development Environment
Eclipse provides a common user interface (UI) model for working with tools. It is designed to run on multiple operating systems while providing robust integration with each underlying OS. Plug-ins can program to the Eclipse portable APIs and run unchanged on any of the supported operating systems [34].

At the core of Eclipse is architecture for dynamic discovery, loading, and running of plug-ins. The platform handles the logistics of finding and running the right code. The platform UI provides a standard user navigation model. Each plug-in can then focus on doing a small number of tasks well [34].

As Eclipse platform has shown in Figure 4.1, it includes the Eclipse Java Development Tools, offering an IDE with a built-in incremental Java compiler and a full model of the Java source files. This allows for advanced refactoring techniques and code analysis. The IDE also makes use of a workspace, in this case a set of metadata over a flat file space allowing external file modifications as long as the corresponding workspace "resource" is refreshed afterwards [35].

Figure 4.1. Eclipse Platform Structure[34]
4.2. AWT
The Standard Widget Toolkit (SWT) is a graphical widget toolkit use for the Java platform. It was developed by IBM and now Eclipse Foundation is maintained for Eclipse IDE [36]. IBM has created a new GUI library, called SWT, which solves the problems seen with the AWT and the Swing frameworks. The SWT framework accesses native widgets through JNI. If a widget is not available on the host platform, SWT emulates the unavailable widget [36] [37].

4.3. Swing
Swing was developed to provide a more sophisticated set of GUI components than the earlier Abstract Window Toolkit (AWT).

Platform Independence: Swing is platform independent both in terms of its expression (Java) and its implementation [36] [37] [38].

Extensibility: Swing is a highly partitioned architecture, which allows for the "plugging" of various custom implementations of specified framework interfaces. Users can provide their own custom implementation(s) of these components to override the default implementations. Swing users can extend the framework by extending existing (framework) classes or providing alternative implementations of core components to modify components according to their requirements [36] [37] [38].

Component Oriented: Swing is a component-based framework. The distinction between objects and components is a fairly subtle point, concisely; a component is a well-behaved object with a known/specified characteristic pattern of behavior. Swing objects asynchronously fire events, have "bound" properties, and respond to a well-known set of commands (specific to the component.) Specifically, Swing components are Java Beans components, compliant with the Java Beans Component Architecture specifications [36] [37] [38].

Customizable: Given the programmatic rendering model of the Swing framework, fine control over the details of rendering of a component is possible in Swing. As a general pattern, the visual representation of a Swing component is a composition of a standard set of elements, such as a "border", "inset", decorations, etc. Typically, users will programmatically customize a standard Swing component (such as a JTable) by assigning specific Borders, Colors, Backgrounds, opacities, etc., as the properties of that component. The core component will then use this property (settings) to determine the appropriate renderers to use in painting its various aspects. However, it is also completely possible to create unique GUI controls with highly customized visual representation [36] [37] [38].

Configurable: Swing's heavy reliance on runtime mechanisms and indirect composition patterns allows it to respond at runtime to fundamental changes in its settings. For example, a Swing-based application can change its look and feel at
runtime. Further, users can provide their own look and feel implementation, which allows for uniform changes in the look and feel of existing Swing applications without any programmatic change to the application code [36] [37] [38].

**Light Weight User Interface:** Swing's configurability is a result of a choice not to use the native host OS's GUI controls for displaying itself. Swing "paints" its controls programmatically through the use of Java 2D APIs, rather than calling into a native user interface toolkit. Thus, a Swing component does not have a corresponding native OS GUI component, and is free to render itself in any way that is possible with the underlying graphics APIs [36] [37] [38].

4.4. Applets

An Applet is a program written in the Java programming language that can be included in an HTML page, much in the same way an image is included in a page. When you use a Java technology-enabled browser to view a page that contains an Applet, the applet's code is transferred to your system and executed by the browser's Java Virtual Machine (JVM) [39][40]. Swing provides a special subclass of Applet, called `javax.swing.JApplet`, which should be used for all applets that use Swing components to construct their GUIs. [40]

4.5. Visualization System Components

In this section, we will discuss some major components of our implemented visualization system. In Figure 4.2, we can see the main components linked with visualization system,

![Figure 4.2. Components of Visualization System](image-url)
We have used a Java Applet in our visualization system for Web Users. JAVA core API’s are used as a main language of our software development. Database is main source of data for our software; we have used MySQL database as an input source (dataset) for our developed visualization tool (CV2DChart).

4.6. Software Development
Our software development contains number of classes like,

<table>
<thead>
<tr>
<th>Class Summary</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ColorManager</td>
<td>This class is, to generate the color code for each attribute, and it is manage by Map, we can also access the color of each attribute directly by calling getColor()</td>
</tr>
<tr>
<td>CV2DChartPanel</td>
<td>This class is use to get information to display chart</td>
</tr>
<tr>
<td>CVApplet</td>
<td>Main client-side, visualization class extends JApplet placed all visual components in this class, and it provides all visual interaction for web user.</td>
</tr>
<tr>
<td>CVColorDialog</td>
<td>Choosing colors with different way to visualiz metrics information</td>
</tr>
<tr>
<td>CVDb</td>
<td>This Class contains different methods to connect with MySql Database and as well different methods to perform DML and DDL queries and return result set</td>
</tr>
<tr>
<td>CVFormComponents</td>
<td>Contains all form component, Which will be use to interact with users like Toolbar, JPanel, Combobox and Text etc</td>
</tr>
<tr>
<td>CVMetricComponent</td>
<td>Contains JPanel, adding pan, trees displaying projects and metrics</td>
</tr>
<tr>
<td>CVProjectComponent</td>
<td>Maintain Project information</td>
</tr>
<tr>
<td>CVTabs</td>
<td>Designing Tabbed Pane and adding tabs</td>
</tr>
<tr>
<td>CVToolBar</td>
<td>Design toolbar adding buttons and action listener for those buttons</td>
</tr>
<tr>
<td>ReadTextFile</td>
<td>Read Metrics Text File and Form Query to insert data into database</td>
</tr>
<tr>
<td>ReadToolTextFile</td>
<td>Read tool text file and form query to update database</td>
</tr>
<tr>
<td>WriteTextFile</td>
<td>Write Text file exporting metrics data from database to a text file over local system.</td>
</tr>
<tr>
<td>CheckNode</td>
<td>Nodes containing check boxes</td>
</tr>
<tr>
<td>CheckNodeTree</td>
<td>A tree containing nodes with check boxes</td>
</tr>
<tr>
<td>CheckRenderer</td>
<td>Managing and manipulating values tree layout and settings</td>
</tr>
</tbody>
</table>

*Table 4.1. List of Classes*
4.6.1. Database Class Diagram

*Figure 4.3* describes the database interaction from different objects of visualization system.

*Figure 4.3. Class Diagram: Database Interaction System*
4.6.2. Visualization Class diagram

The class diagram in Figure 4.4, describes the complete interaction of visualization system with other objects of implemented application.

Figure 4.4. Class Diagram: Visualization System
4.6.3. User Interface Class Diagram
This class diagram in Figure 4.5, is explaining the Web Application Interface of implemented visualization application.

Figure 4.5. Class Diagram: Web Application
4.6.4. Color Manager
This class is used to generate the color code for each attribute, and it is managed by Map, we can also access the color of each attribute directly by calling getColor().

![Class Design Diagram](image)

**Figure 4.6. ColorManager: Class Design Diagram**

```java
public class ColorManager
    extends java.lang.Object
{
    public ColorManager()
    {
    }
    public void createMetricsColorMapExperimentA(Set<Integer> set)
    {
    }
    public void createMetricsColorMapExperimentB(Set<Integer> set)
    {
    }
    public void createMetricsColorMapExperimentC(Set<Integer> set)
    {
    }
    public void createProjectsColorMap()
    {
    }
    public Color getColor()
    {
    }
    public Color getMetricColor()
    {
    }
    public Color getProjectColor()
    {
    }
}
```

**Field Summary**

- `metricsColorMap` contains set of metric ids along their colors code
- `projectsColorMap` contains set of project ids along their colors code

**Constructor Summary**

- `ColorManager()` default constructor

**Method Summary**

- `void createMetricsColorMapExperimentA(Set<Integer> set)` Random color generation
- `void createMetricsColorMapExperimentB(Set<Integer> set)` This method allows the computation of Experiment-B
- `void createMetricsColorMapExperimentC(Set<Integer> set)` This method allows the computation of Experiment-C
Table 4.2. Class Description: ColorManager

4.6.5. CV2DChartPanel
This class is use to display line charts (visualization).

Figure 4.7. CV2DChartPanel: Class Design Diagram
### Field Summary

<table>
<thead>
<tr>
<th>Type</th>
<th>Field</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>String</td>
<td>analysis_type</td>
<td>store analysis type</td>
</tr>
<tr>
<td>Integer</td>
<td>analysis_type_id</td>
<td>store analysis type id</td>
</tr>
<tr>
<td>String</td>
<td>analysis_table</td>
<td>store analysis type table</td>
</tr>
<tr>
<td>ZoomableChart</td>
<td>chart</td>
<td>object of zoomable chart class</td>
</tr>
<tr>
<td>ColorManager</td>
<td>cm</td>
<td>object of color manager class</td>
</tr>
<tr>
<td>String</td>
<td>experimentType</td>
<td>store experiment type</td>
</tr>
<tr>
<td>JPanel</td>
<td>frame</td>
<td>JPane Object</td>
</tr>
<tr>
<td>Map&lt;Integer,String&gt;</td>
<td>metricsMap</td>
<td>maintain metric list</td>
</tr>
<tr>
<td>Map&lt;Integer,List&lt;Integer&gt;&gt;</td>
<td>projectList</td>
<td>maintain projects list</td>
</tr>
<tr>
<td>Map&lt;Integer,LinkedHashSet&lt;Integer&gt;&gt;</td>
<td>projectsMap</td>
<td>maintain project and version list</td>
</tr>
<tr>
<td>Integer</td>
<td>tool_id</td>
<td>store tool id</td>
</tr>
<tr>
<td>String</td>
<td>tool_name</td>
<td>store tool name</td>
</tr>
<tr>
<td>String</td>
<td>tool_version</td>
<td>store tool version</td>
</tr>
<tr>
<td>Integer</td>
<td>tool_version_id</td>
<td>store tool version id</td>
</tr>
</tbody>
</table>

### Constructor Summary

`CV2DChartPanel(String experimentType)`
- default constructor
Method Summary

<table>
<thead>
<tr>
<th>Method Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>addVisualizationMethod1()</td>
<td>this method is used for, Experiment: A, B, D, F</td>
</tr>
<tr>
<td>addVisualizationMethod2()</td>
<td>this method is used for, Experiment: C, E</td>
</tr>
<tr>
<td>getAnalysis_type_id()</td>
<td>get the type id of analysis (either class, method, package, etc...) used for this visualization</td>
</tr>
<tr>
<td>getAnalysis_type()</td>
<td>get the analysis type</td>
</tr>
<tr>
<td>getAnalysis_table()</td>
<td>get the name of analysis table in database</td>
</tr>
<tr>
<td>getMetricsMap()</td>
<td>get the map of metrics id's with their names</td>
</tr>
<tr>
<td>getProjectsMap()</td>
<td>get the map&gt; of selected projects with their versions list</td>
</tr>
<tr>
<td>getTool_id()</td>
<td>get the analysis tool id of this visualization chart</td>
</tr>
<tr>
<td>getTool_name()</td>
<td>get the name of analysis tool</td>
</tr>
<tr>
<td>getTool_version_id()</td>
<td>get the version number of analysis tool</td>
</tr>
<tr>
<td>getTool_version()</td>
<td>get the version name of analysis tool</td>
</tr>
</tbody>
</table>

Table 4.3. Class Description: CV2DChartPanel

4.6.6. CVApplet
It is an applet class use to instantiate the application, manage application with web browser. Main client-side, visualization class extends JApplet placed all visual components in this class, and it provides all visual interaction for web user.

Figure 4.8. CVApplet: Class Design Diagram
4.6.7. CVColorDialog
Helper class is displaying the Metrics and Projects Color information.

Figure 4.9. CVColorDialog: Class Design Diagram
public class CVColorDialog extends javax.swing.JPanel implements javax.swing.ListCellRenderer

<table>
<thead>
<tr>
<th>Field Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>protected Color m_c</td>
</tr>
<tr>
<td>color’s information</td>
</tr>
<tr>
<td>Protected JLabel m_l</td>
</tr>
<tr>
<td>label object</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Constructor Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>CVColorDialog()</td>
</tr>
<tr>
<td>default constructor</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Method Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Component getListCellRendererComponent(JList list, Object obj, int row, boolean sel, boolean hasFocus)</td>
</tr>
<tr>
<td>Void paint(Graphics g)</td>
</tr>
<tr>
<td>Graph drawing</td>
</tr>
</tbody>
</table>

Table 4.5. Class Description: CVColorDialog

4.6.8. CVDb
This Class contains different methods to connect with MySql Database and as well different methods to perform DML and DDL queries. This Class contains different methods to connect with MySql Database and as well different methods to perform DML and DDL queries and return result set.

Figure 4.10. CVDb (Database Handler): Class Design Diagram
Class CVDb
java.lang.Object

public class CVDb
extends java.lang.Object

Field Summary

<table>
<thead>
<tr>
<th>Field</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>connection</td>
<td>MySql connection object</td>
</tr>
<tr>
<td>database</td>
<td>store database name</td>
</tr>
<tr>
<td>password</td>
<td>store password</td>
</tr>
<tr>
<td>user</td>
<td>store user name</td>
</tr>
</tbody>
</table>

Constructor Summary

CVDb(String database, String user, String password)
Establish a connection passing database name, user name and password

Method Summary

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>connect()</td>
<td>Establish connection with database</td>
</tr>
<tr>
<td>disconnect()</td>
<td>Disconnecting with database</td>
</tr>
<tr>
<td>queryDDL(String query)</td>
<td>Passing DDL query and returns true if successfully</td>
</tr>
<tr>
<td>queryDML(String query)</td>
<td>Passing DML Query and returns a result set</td>
</tr>
</tbody>
</table>

Table 4.6. Class Description: CVDb
4.6.9. CVFormComponent
Contains all form component, which will be use to interact with users like Toolbar, JPanel, Combobox and Text etc.

![Figure 4.11. CVFormComponent: Class Design Diagram](image)

```
class CVFormComponents
extends java.lang.Object

Field Summary
CVDb                     db
Object for class cvdb

Constructor Summary
CVFormComponents()

Method Summary
JPanel               designForm()
                    designing overall components over a form
static Integer      getAnalysisTypeID()
                    retrieving analysis type id from the table
static String       getAnalysisTypeName()
                    retrieving analysis type name
static String       getAnalysisTypeTableName()
                    retrieving analysis type name from the table
static Integer      getToolID()
                    retrieving tool id from tool table
```
<table>
<thead>
<tr>
<th>static String</th>
<th>getToolName()</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>retrieving tool name from the tool table</td>
</tr>
<tr>
<td>static Integer</td>
<td>getToolVersionID()</td>
</tr>
<tr>
<td></td>
<td>retrieving tool version id from tool version table</td>
</tr>
<tr>
<td>static String</td>
<td>getToolVersionName()</td>
</tr>
<tr>
<td></td>
<td>retrieving tool version name from tool version table</td>
</tr>
</tbody>
</table>

**Table 4.7. Class Description: CVFormComponent**

### 4.6.10. CVMetricComponent

Contains JPanel, adding pan, trees displaying projects and metrics

**Figure 4.12. CVMetricComponent: Class Design Diagram**

```
client
Class CVMetricComponent
  java.lang.Object
    client.CVMetricComponent

Constructor Summary
CVMetricComponent(JPanel panel)

Method Summary
  static void addPane()
    Adding pane
  static Map<Integer,String> getSelectedMetrics()
    this method returns the selected metrics with metric-id
  static void removePane()
    remove Metrics tree
```

**Table 4.8. Class Description: CVMetricComponent**
4.6.11. CVProjectComponent
Maintain Project information

```java
public class CVProjectComponent
extends java.lang.Object

Constructor Summary
CVProjectComponent(JPanel panel)

Method Summary
static void addPane()
   Adding pane

static String getProjectName(Integer projectId)
   Get project name from the project table

static String getProjectVersionName(Integer projectVersionId)
   Get project version name from table project version

static Integer getProjectVersionOrderNumber(Integer projectVersionId)
```

Figure 4.13. CVProjectComponent: Class Design Diagram

Client

Class CVProjectComponent
   java.lang.Object
      client.CVProjectComponent

public class CVProjectComponent
extends java.lang.Object
retrieve project version order numbering to arrange versions

<table>
<thead>
<tr>
<th>static Map&lt;Integer, List&lt;Integer&gt;&gt;</th>
<th>getSelectedProjectList()</th>
</tr>
</thead>
<tbody>
<tr>
<td>retrieve selected project from the list</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>static Map&lt;Integer, LinkedHashSet&lt;Integer&gt;&gt;</th>
<th>getSelectedProjectMap()</th>
</tr>
</thead>
<tbody>
<tr>
<td>get map from selected project list</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>static void</th>
<th>removePane()</th>
</tr>
</thead>
<tbody>
<tr>
<td>remove Project tree (from '0' location / index)</td>
<td></td>
</tr>
</tbody>
</table>

**Table 4.9. Class Description: CVProjectComponent**

### 4.6.12. CVTabs
Designing Tabbed Pane and adding tabs in this class.

#### Figure 4.14. CVTabs (Tabs Controller): Class Design Diagram

```java
public class CVTabs extends java.lang.Object {

  private javax.swing.JTabbedPane pane;
  private CVFormComponents startTab;

  CVTabs() {
    designTabs();
  }

  public void designTabs() {
    // Adding tabs and labels
  }
}
```

**Table 4.10. Class Description: CVTabs**
4.6.13. CVToolBar
In this class, design toolbar adding buttons and action listener for those buttons.

![Class Design Diagram](image)

**Figure 4.15. CVToolBar (Tool Bars): Class Design Diagram**

**Class CVToolBar**
java.lang.Object
  - java.awt.Component
    - java.awt.Container
      - javax.swing.JComponent
        - javax.swing.JPanel
          - client.CVToolBar

**Direct Known Subclasses:**

public class CVToolBar
extends javax.swing.JPanel
implements java.awt.event.ActionListener
### Nested Class Summary

<table>
<thead>
<tr>
<th>Class</th>
<th>CVToolBar.ToolBarA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>inner class</td>
</tr>
<tr>
<td>Class</td>
<td>CVToolBar.ToolBarB</td>
</tr>
<tr>
<td></td>
<td>inner class</td>
</tr>
<tr>
<td>Class</td>
<td>CVToolBar.ToolBarC</td>
</tr>
<tr>
<td></td>
<td>inner class</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Field Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>protected int</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Constructor Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>CVToolBar()</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Method Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Void</td>
</tr>
<tr>
<td>actionPerferred(ActionEvent arg0)</td>
</tr>
<tr>
<td>event handler</td>
</tr>
<tr>
<td>CVToolBar</td>
</tr>
<tr>
<td>addToolObject(CV2DChartPanel chartData)</td>
</tr>
<tr>
<td>adding tool object chart etc</td>
</tr>
<tr>
<td>CVToolBar</td>
</tr>
<tr>
<td>addToolObject(int key)</td>
</tr>
<tr>
<td>adding toolbar objects</td>
</tr>
<tr>
<td>protected JButton</td>
</tr>
<tr>
<td>makeNavigationButton(String imageName,String actionCommand,String toolTipText, String altText)</td>
</tr>
<tr>
<td>handling navigation of JButton</td>
</tr>
</tbody>
</table>

*Table 4.11. Class Description: CVToolBar*
4.6.14. ReadTextFile
In this class, Read Metrics Text File to insert appropriate data into database.

![Class Diagram](image)

**Class ReadTextFile**
`java.lang.Object`  
`- client.ReadTextFile`

```java
public class ReadTextFile  
extends java.lang.Object
```

<table>
<thead>
<tr>
<th>Field Summary</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><code>Connection</code></td>
<td>conn</td>
</tr>
<tr>
<td><code>List&lt;Integer&gt;</code></td>
<td>countList</td>
</tr>
<tr>
<td><code>CVDb</code></td>
<td>Db</td>
</tr>
<tr>
<td><code>String</code></td>
<td>projectID</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Constructor Summary</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>ReadTextFile()</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Method Summary</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><code>String</code></td>
<td>buildFieldsString(String line)</td>
</tr>
<tr>
<td>Build Field String for Query eg.</td>
<td></td>
</tr>
<tr>
<td><code>String</code></td>
<td>buildValuesString(String line)</td>
</tr>
<tr>
<td>Build Value String for query eg.</td>
<td></td>
</tr>
</tbody>
</table>
String  | getAnalysisTableInfo(String tool_Version_ID, String metric_Type)
| return table_name and type_id if it contains in database else null

Map<String,Double>  | getMetricDefaultVal(String tool_Version_ID,String type_Id)
| return list of of default value for metrics available in database e.g LOC = 3

Boolean  | getProject(String name)
| get Project ID for a given project

String  | getProjectVersion(String name, String version)
| return project_version_id if database contains and else return null

String  | getToolInfo(String toolName, String version)
| return tool_version_id if it contains in database else return null

Void  | readMetricFile(File file)
| Read Text File matrices information

Void  | updateDB(String table, String fields, String values)
| insert query to update database

| Table 4.12. Class Description: ReadTextFile |

4.6.15. ReadToolTextFile
In this class, reading tool text file and form query to update database.

| Figure 4.17. ReadToolTextFile: Class Design Diagram |

client
Class ReadToolTextFile
java.lang.Object
  client.ReadTextFile
    client.ReadToolTextFile

public class ReadToolTextFile
extends ReadTextFile
### Constructor Summary

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>ReadToolTextFile()</code></td>
<td></td>
</tr>
</tbody>
</table>

### Method Summary

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>boolean containRecord(String table, String fields, String criteria)</code></td>
<td>Return true if a table contains record at given criteria else return false</td>
</tr>
<tr>
<td><code>String getAnalysisTypeID(String typeName, String table_Name)</code></td>
<td>Return Type_ID if it contains else return null</td>
</tr>
<tr>
<td><code>String getToolId(String toolName)</code></td>
<td>Return tool Id if it contains else return null</td>
</tr>
<tr>
<td><code>String getToolVersionId(String toolId, String Version)</code></td>
<td>Return tool_version_id if it contains else return null</td>
</tr>
<tr>
<td><code>void readToolFile(File file)</code></td>
<td>Read a text file from a given directory and update database while reading text file contents</td>
</tr>
</tbody>
</table>

### Table 4.13. Class Description: ReadToolTextFile

<table>
<thead>
<tr>
<th>Table 4.13. Class Description: ReadToolTextFile</th>
</tr>
</thead>
</table>

### 4.6.16. WriteTextFile

In this class, writing Text file exporting metrics data from database to a text file over local system.

#### Figure 4.18. WriteTextFile: Class Design Diagram

```plaintext
client
Class WriteTextFile
java.lang.Object
  └──client.WriteTextFile
```

#### Field Summary

<table>
<thead>
<tr>
<th>Field</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Writer</td>
<td>output writer object</td>
</tr>
</tbody>
</table>
**Constructor Summary**

<table>
<thead>
<tr>
<th>Constructor</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>WriteTextFile(java.io.File file, CV2DChartPanel chartData)</td>
<td>create a text file in given directory and write tool, project and metrics information</td>
</tr>
</tbody>
</table>

Table 4.14. Class Description: WriteTextFile

4.6.17. CheckNode

This class, create check nodes in a tree list.

![CheckNode: Class Design Diagram](image)

Figure 4.19. CheckNode: Class Design Diagram

```java
client.util.checkbox
Class CheckNode
java.lang.Object
    └── javax.swing.tree.DefaultMutableTreeNode
    └── client.util.checkbox.CheckNode
```

```java
public class CheckNode extends javax.swing.tree.DefaultMutableTreeNode
```

**Field Summary**

<table>
<thead>
<tr>
<th>Field Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>static int</td>
<td>DIG_IN_SELECTION store selection value</td>
</tr>
<tr>
<td>protected Boolean</td>
<td>isSelected Boolean true or false</td>
</tr>
<tr>
<td>protected int</td>
<td>selectionMode store selection mode value</td>
</tr>
</tbody>
</table>
## Constructor Summary

- **CheckNode()**  
  Check Node keep the record of all nodes added as parent and child nodes

- **CheckNode(Object userObject, boolean allowsChildren, boolean isSelected)**

- **CheckNode(Object userObject, int id)**

## Method Summary

<table>
<thead>
<tr>
<th>Type</th>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Int</td>
<td>getID()</td>
<td>Get id of the node</td>
</tr>
<tr>
<td>Int</td>
<td>getSelectionMode()</td>
<td>Get Selection mode</td>
</tr>
<tr>
<td>Boolean</td>
<td>isSelected()</td>
<td>Return true or false if a node is selected or not</td>
</tr>
<tr>
<td>Void</td>
<td>setSelected(boolean isSelected)</td>
<td>Setting a node to be selected</td>
</tr>
<tr>
<td>Void</td>
<td>setSelectionMode(int mode)</td>
<td>Set Selection Mode</td>
</tr>
</tbody>
</table>

**Table 4.15. Class Description: CheckNode**

### 4.6.18. CheckNodeTree

This class manages checkNode with tree check box system.

![CheckNodeTree](image)

**Figure 4.20. CheckNodeTree: Class Design Diagram**

51
public class CheckNodeTree
extends java.lang.Object

<table>
<thead>
<tr>
<th>Nested Class Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Constructor Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>CheckNodeTree()</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Method Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>JScrollPane</td>
</tr>
<tr>
<td>addNode(CheckNode root)</td>
</tr>
<tr>
<td>Adding list of CheckNode to JTree</td>
</tr>
</tbody>
</table>

Table 4.16. Class Description: CheckNodeTree

### 4.6.19. CheckRenderer

This class manages and manipulates values tree layout and settings.

![Class Design Diagram](image)

Figure 4.21. CheckRenderer: Class Design Diagram
Class CheckRenderer
java.lang.Object
  ↓ java.awt.Component
  ↓ java.awt.Container
  ↓ javax.swing.JComponent
  ↓ javax.swing.JPanel
  ↓ client.util.checkbox.CheckRenderer

extends javax.swing.JPanel
implements javax.swing.tree.TreeCellRenderer

### Nested Class Summary

<table>
<thead>
<tr>
<th>Class</th>
<th>CheckRenderer.TreeLabel Renderer tree label</th>
</tr>
</thead>
</table>

### Field Summary

<table>
<thead>
<tr>
<th>Field</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>protected JCheckBox</td>
<td>check</td>
</tr>
<tr>
<td>protected CheckRenderer.TreeLabel</td>
<td>label</td>
</tr>
</tbody>
</table>

### Constructor Summary

<table>
<thead>
<tr>
<th>Constructor</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CheckRenderer()</td>
<td></td>
</tr>
</tbody>
</table>

### Method Summary

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Void doLayout()</td>
<td>Setting layout for label and check box</td>
</tr>
<tr>
<td>Dimension getPreferredSize()</td>
<td>Get Pregered size for lable and text</td>
</tr>
<tr>
<td>Component</td>
<td>getTreeCellRendererComponent(JTree tree, Object value, boolean isSelected, boolean expanded, boolean leaf, int row,boolean hasFocus)</td>
</tr>
<tr>
<td>Void setBackground(Color color)</td>
<td>Setting background color</td>
</tr>
</tbody>
</table>

*Table 4.17. Class Description: CheckRenderer*
4.6.20. Collaboration Diagram of Visualization System

Figure 4.22. Collaboration Diagram: Visualization System

Figure 4.22 shows the internal implementation of components, drawing canvas and operation over drawing like zooming, exporting image and zoom options as well.
4.6.21. Collaboration Diagram of Tool Input File

Figure 4.23. Collaboration Diagram: ReadToolTextFile

Figure 4.23 shows the implementation of reading tool text file and building the fields and value to update database.
4.6.22. Collaboration Diagram of Metrics Input File

![Collaboration Diagram of Metrics Input File]

**Figure 4.24. Collaboration Diagram: Read Metrics Dataset**

*Figure 4.24 shows the implementation of reading metric text file and building the fields and value to update database.*
5. User Interaction and System Dialogs

In this Chapter, we will discuss how user can interact with system. These techniques allow the user to compare and analyze large projects having different improve versions. Below, we will explain our system with the help figure taken from the system.

5.1. Main Controller Window

This is the main interface for users to operate with the complete application. It contains a toolbar having buttons upload tool data and import metric data.

![Screen Shorts: Main Window](image)

*Figure 5.1. Screen Shorts: Main Window*

5.2. Upload Tool Information

The *Figure 5.2* represents format of our text file to import data from user end to server side which will be manage by DBMS. From start, we write some tag in following format `<>`, to identify the sequence of data, second line represents fields that are identifiable by the system. The following text file displays the contents of a tool text file which is acceptable by the system.
To upload tool data, following steps are necessary to perform and follow the text file pattern given below. User must provide tool information as shown in a text file.
1. From main application toolbar, click on upload tool data button.
2. Select a text file containing tool data
3. Successfully upload message appears

Figure 5.3. Screen Shorts: Tool File Format
5.3. Upload Metric Data

The Figure 5.4 represents format of our text file to import Metrics data from user end. From start we write some tag in a <>, to identify the sequence of data, second line represents fields that are identifiable by the system.

Following steps are helpful to upload metric data into the system
1. From main application toolbar, click on upload Metric Data button.
2. Select a text file containing metric data
3. Successfully upload message appears

Figure 5.4. Screen Shorts: Metric data format

Figure 5.5. Screen Shorts: Three steps to store metrics data
5.4. **Make Selection**
To visualize the project first of all user must enter some detail about tool and analysis type while selecting data from combo boxes on start pane. Clicking on next will provide some more details displayed in next figure.

![Figure 5.6. Screen Shorts: Main Form](image1)

After clicking next user will be able to see to check box trees, on left hand it displays number of projects available in information system and in other hand metrics supported by the selected tool is also available.

![Figure 5.7. Screen Shorts: List of Projects and Metrics](image2)
User must select the projects and metrics of his choice by clicking over the checkboxes in the tree. All checkboxes can be selected by clicking over the root check box. Project Metrics panel also contain a tool bar where only one button describing the visualizing.

![Screen Shorts: Make selection for visualization](image)

Figure 5.8. Screen Shorts: Make selection for visualization

After clicking on visualization button, user can view the projects and metrics in form of 2D-Charts. As Figure 5.9 describes the best,

![Screen Shorts: Visualization result](image)

Figure 5.9. Screen Shorts: Visualization result
5.5. Exporting Metric Data

Exporting metric data of visualization (Figure 5.10), steps are written below
1. Click on the current visualization toolbar and click export drawing data button from toolbar.
2. Provide Path and folder name.

Figure 5.10. Screen Short: Exporting Metric Data

Figure 5.11. Screen Short: New directory
In Figure 5.11, jEdit (Project) metric data files display in explorer window starting with project id, and ending with version id.

5.6. Data Points
Visualization metric can be displayed in Figure 5.12,

![Data Point Visualization](image).

Figure 5.12. Screen Short: Data Point

5.7. Zoom Out

![Zoom Out](image).

Figure 5.13. Screen Short: Zooming data point
User can zoom out drawing by selecting specific area, it expands the selected area and user can visualized data points more clearly. It is useful when lines are much closer with each other.

![Screen Short: Zooming result of selected point](image)

**Figure 5.14. Screen Short: Zooming result of selected point**

To shrink drawing to its original size, click on zoom button available in toolbar as displayed in *Figure 5.14*.

5.8. **Export Drawing as Image**
User can save image data and as well it can also save current image while clicking on the button given in the toolbar.

![Screen Short: Export chart as a image format](image)

**Figure 5.15. Screen Short: Export chart as a image format**

5.9. **Print Drawing**
This option allows user to get drawing hard copy, provides additional feature to support user and ease of the using the system.
Summary
In this chapter, we discuss all possibilities how user can interact with the system and how he/she can visualize projects and their metrics information, which are supportive to assess and reach over a final decision.
6. Case Study
In this chapter we explain few possible scenarios, how we can visualize quality metrics value with respect to project version using different techniques and methods? As, all scenarios are based on 2D-Charts, where Average Value of software metric is along Y-Axis and Project Version is along X-Axis. Case studies A to F contains detail explanations.

6.1. Case Study A
In Case Study A, we have focus on colors for Metrics. Therefore we choose random color of circle (glyph object) to identify different Quality Metrics (LOC, NOM, WMC …).

Figure 6.1. Case Study-A: Visualizing LOC, CYC Metrics

Figure 6.1, displays project tomcat with two different metrics LOC, CYC. In this visualization each metric has different color. In this Case Study, colors of metrics look similar and it is very difficult to differentiate different metrics due to minor changes in their colors.

6.2. Case Study B
The main task in Case Study B is to display circle colors uniquely, as we used RGB colors, for example Red=1, then ‘1’ will never repeat again for Red next time.
In Figure 6.2, we can perceive the Metric colors easily. It is better approach then using the random colors where same pallet color is possible to be repeated.

6.3. Case Study C
In this Case Study, we compute the data points by calculating the average values of all selected Metrics.

In Case Study C, Viewer can see the trend of any project for given Quality Metrics. This technique is very help full, when user has multiple Projects with multiple Metrics.

6.4. Case Study D
In Case Study D, we try to avoid the colors that are almost same with minor difference. We are dealing with RGB colors in our code and to make some
difference among the colors. We reserve 10 from left and 10 from right to avoid similar color perception. For example, R=100 then we reserve R from 91 to 100 and 100 to 110.

Figure 6.4. Case Study-D: Visualizing LOC, CYC Metrics

The Figure 6.4 has better results than Case Study A and B. User can easily perceive the both Metrics by their Colors.

6.5. Case Study E
In Case Study E, we combined metrics by computing average value of selected metrics with respect to complexity, structure and maintainability. Each measurement is shown by single line for each project.

Figure 6.5. Case Study-E: Average data points of LOC and CYC

In Case Study E, idea is useful when we want to visualize large number of projects and user is unable to assess the desire results then the following Case Study is useful. In other scenario when user requirement is limited and want
assess metrics individually then other approaches are useful for user then the approach explain and shown in Figure 6.5.

6.6. **Case Study F**
In *Case Study F*, display metrics and project version details by text instead of using circle. In this approach circle is removed and text is displayed as shown in Figure 6.6.

![Figure 6.6. Case Study-F: Visualizing text glyph LOC, CYC Metrics](image)

*Case Study F* is an alternative technique using text nodes instead of circles. But in this technique visualization is not better than the previous one. Circle fill with color is a better technique as used in previous *Case Study*.

6.7. **Summary**
We discussed different case studies of visualization of statistical contents of software projects. Conclusion and final results of above *Case Studies* will be explained in the following chapter (*Section 7.1*).
7. Conclusion

Our intent in this thesis was to research and develop visualization techniques to visualize statistical content of software’s. In this chapter, we will discuss our achievement of this research project. We will also explain future work that is related to our proposed visualization techniques.

7.1. Results

In this thesis, we have presented few case studies (Chapter 6) for analysis of software projects with different software quality metrics, i.e., a statistical contents are the main input of these visualizations. All case studies are useful in different perspectives, but our focus is to find out the best visualization approaches to display analysis of software projects. We have introduced a 2D chart for the visualization of software metrics along respective projects versions, and it is used for all test cases. Here we will describe the solution of already defined objectives (Section 1.3) of this project.

- Design graphical representation of statistical contents using 2D-Graphics.
- To implement a visualization technique that is more user friendly and time efficient for a large dataset.
- Develop a Web-Service that provides the interface between online Visualization-Tool and Database.
- Construct the new dataset by computing the average values of all attributes of each project.
- Develop the Web-Based visualization tool on client-side.
- Develop the server-side tool to upload the metrics data of projects along their version information into database.

7.1.1. Graphical Representation

A very first goal of this project was to implement a graphical representation of statistical contents using 2-D Graphics. As in Chapter 2, we discussed previous work of Chart Graphics for visualization of statistical contents of software’s. In our study, we found a research work related to visualization of software projects through different chart graphical representation, and we were decided to develop Line Chart graphical representation for visualization of statistical contents of software projects.

7.1.2. Visualization Techniques

Here, we have used different visualization techniques to analyze our visualization tool (ChartVizz2D). Our main focus in this comparison test is perception and better understanding of visualization. As the ChartVizz2D is a visualization tool for statistical contents of software projects, we should also analyze the performance of our system by direct human interaction. In this case, I have chosen three friends of mine from the group of Software Technology, MSI, Vaxjo University to compare the visualization performance of all approaches (Chapter
They have analyzed different case studies, and finally all of them agreed that our visualization *Case Studies D (Section 6.4) and E (Section 6.5)*, both are easy to perceive and better to understand. *Case Study D* is useful to compare multiple *Software Metrics* of either same *Project* or multiple *Projects*. And *Case Study E* is useful to compare *Combined Software Metrics* (Collection of Software Metrics) of different *Projects*.

As we have introduced a zooming technique to visualize the data points more clearly. This technique makes user friendly and also this is time efficient access to get the any data point in constant time \( O(1) \).

Our implemented web application is also time efficient for large dataset. As we tested our tool on real dataset, as explain below,

**Testing Platform**
We have tested the application in client server environment. We have following client side hardware and software components for the testing of our web application in real time.

- **Operating System:** Window 7 SP1
- **Machine:** Dell XPS 16 2.0 G, Core2Duo Intel inside
- **RAM:** 3GB
- **Web Browser:** Internet Explorer 8.0
- **Tool:** Java Virtual Machine (JVM)

Now, simply we need to access the web address of our developed application on client side and test it through different scenarios.

**Given Input Dataset-1**
*Project:* Tomcat
*Versions:* 18
*Quality Metrics:* 3
*Approximate dataset size:* 1.3+ Millions Records in MySQL database
**Application takes 15sec. 82msec to execute.**

**Given Input Dataset-2**
*Project:* Tomcat
*Versions:* 18
*Quality Metrics:* 17
*Approximate dataset size:* 1.3+ Millions Records in MySQL database
**Application takes 01min. 34sec to execute.**

As we can see in above two datasets, dataset (1) with low number of *Metrics* is faster than other dataset (2).
7.1.3. Database Interface
This is important objective of our application; *CVDb* is a class to establish a connection between *Web Applet* and *MySQL* database. This interface can be use for both DML (Data Manipulation Language) and DDL (Data Definition Language) queries.

7.1.4. Web Application
We designed and developed the *Web* application for visualization of statistical contents of software projects. We had used *Java Applets* to develop our proposed visualization system.

7.1.5. Utilities
In this section, we cover other utilities or facilities for our application. These include following,

- download the statistical contents of software project.
- upload of projects dataset into database.
- download and upload of analysis tool information.
- zooming option in *2D Chart Panel*.
- exporting visualization results into *jpeg* format.
- printing the visualization results.

7.1.6. Deployment
Finally, we have deployed the application in real time (Client-Server) environment. We installed the following required components on host server,

- Window Server
- Apache Tomcat 6.0.29
- MySQL Server 5.1.50
- Developed Proposed Application (ChartVizz.jar)

In final version, we have uploaded the 18 Projects into MySQL database. Approximately each project contains 8 to 20 versions history. The size of deployed database is *1392807 ROWS* (1.3+ Million records) that is 256+ MB.

7.2. Future Work
This thesis presented a visualization of statistical contents of software projects through different case studies. After the completion of this project, we conclude with the following future work:

- Improve the data structure to accommodate the dataset.
- To load large datasets into the program memory faster than now.
- More work on zooming feature in our visualization application.
- Extend to flexible displays, especially for large screens, projectors etc.
- To compute input dataset with other statistical formulas (like, mean, standard error, median, modus, standard deviation, kurtosis, skewness, range, minimum, maximum, sum, count).
## 8. Glossary

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2D</td>
<td>2 Dimension</td>
</tr>
<tr>
<td>ChartViz2D</td>
<td>2 Dimensional Charts Visualization</td>
</tr>
<tr>
<td>API</td>
<td>Application Programming Interface</td>
</tr>
<tr>
<td>AWT</td>
<td>Abstract Window Toolkit</td>
</tr>
<tr>
<td>EMF</td>
<td>Eclipse Model Framework</td>
</tr>
<tr>
<td>GEF</td>
<td>Graphical Editing Framework</td>
</tr>
<tr>
<td>GUI</td>
<td>Graphic User Interface</td>
</tr>
<tr>
<td>IDE</td>
<td>Integrated Development Environment</td>
</tr>
<tr>
<td>JDK</td>
<td>Java Development Kit</td>
</tr>
<tr>
<td>JDT</td>
<td>Java Development Tools</td>
</tr>
<tr>
<td>LWS</td>
<td>Light Weight System</td>
</tr>
<tr>
<td>MVC</td>
<td>Model-View-Controller</td>
</tr>
<tr>
<td>OMT</td>
<td>Object Modeling Technique</td>
</tr>
<tr>
<td>OOSE</td>
<td>Object-Oriented Software Engineering</td>
</tr>
<tr>
<td>PDE</td>
<td>Plug-in Development Environment (PDE)</td>
</tr>
<tr>
<td>SDK</td>
<td>Software Development Kit</td>
</tr>
<tr>
<td>UML</td>
<td>Unified Modeling Language</td>
</tr>
<tr>
<td>JVM</td>
<td>Java Virtual Machine</td>
</tr>
</tbody>
</table>
9. References


[10] *Visualizing Multidimensional Query Results Using Animation*, Amit P. Sawanta and Christopher G. Healey, North Carolina State University, Department of Computer Science, Raleigh, NC, USA.


April 4, 2009