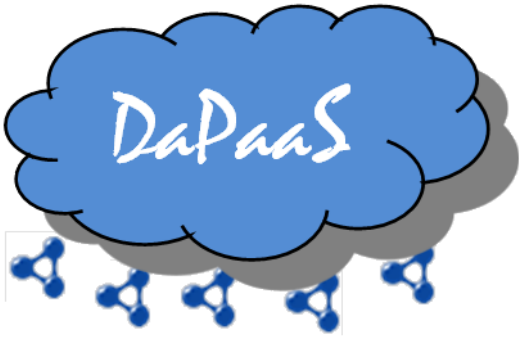
Small or medium-scale focused research project (STREP)

**ICT SME-DCA Call 2013**
FP7-ICT-2013-SME-DCA

# Data Publishing through the Cloud: A Data- and Platform-as-a-Service Approach to Efficient Open Data Publication and Consumption

**DaPaaS**




## Deliverable 3.1

# Analysis, requirements, design & architecture specification for the data access framework

| | |
|---|---|
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| Dissemination level: | PU |
| WP: | 3 |
| Version: | 1.0 |

# Document metadata

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## Version history

| Version | Date | Description |
|---|---|---|
| 0.1 | 05.01.2014 | Initial version – structure of document |
| 0.2 | 10.01.2014 | Added review of relevant tools |
| 0.3 | 20.01.2014 | Addressing initial comments on the document |
| 0.4 | 21.01.2014 | Revised Intro & State of the Art sections |
| 0.5 | 22.01.2014 | Addressing second review of document |
| 0.6 | 32.01.2014 | Added Appendix with reviewed frameworks |
| 0.7 | 28.01.2014 | Internal reviews |
| 1.0 | 31.01.2014 | Final draft |

# Executive Summary

The main goal of the DaPaaS project is to provide an integrated Data-as-a-Service (DaaS) and Platform-as-a-Service (PaaS) environment, together with associated services, for open data, where 3rd parties can publish and host both datasets and data-driven applications that are accessed by end-user data consumers in a cross-platform manner.

This deliverable focuses on the UX aspect of the DaPaaS Platform and provides:

- A summary of the high-level requirements which the UX layer should support;
- A set of requirements on visualization types the platform should support;
- A state-of-the-art overview of how relevant DaaS and integrated DaaS and PaaS solutions deal with data visualization aspects;
- An initial architecture design for relevant aspects of the UX layer (including supported visualization types and mechanisms to deal with efficient access to data from multi-devices); and
- An overview of 3rd party visualization tools and libraries which are potentially relevant for the implementation of the data layer.

This deliverable is aligned and should be read in conjunction with the corresponding deliverables in WP2 (D2.1) and WP1 (D1.1). The outlined UX layer design will be implemented by M9 (D3.2) and further refined during the second year of the project based on user feedback.

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# 1 Introduction

This report represents Deliverable D3.1 "Analysis, requirements, design & architecture specification for the data access framework" of the DaPaaS project. This deliverable is a result of Task T3.1 "Requirements, analysis & design of the framework for data access ".

The goals of this deliverable are to provide:

- A summary of the high-level requirements which the UX layer should support;
- A set of requirements on visualization types the platform should support;
- A state-of-the-art overview of how relevant DaaS and integrated DaaS and PaaS solutions deal with data visualization aspects;
- An initial architecture design for relevant aspects of the UX layer (including supported visualization types and mechanisms to deal with efficient access to data from multi-devices);
- An overview of 3rd party visualization tools and libraries which are potentially relevant for the implementation of the data layer;
- Some recommendations for the use of visualization tools and libraries for the first prototype of the UX Layer.

In line with the overall DaPaaS Platform architecture introduced in deliverable D2.1, the DaPaaS platform (Figure 1) is roughly divided into three layers, covering aspects related to data management, application management and UX (including data-driven portals and mobile access). The core role of the UX layer is two-fold:

1. To provide graphical user interfaces for components developed at the Platform and Data Layers, and access to the data and data intensive applications deployed on the DaPaaS Platform;
2. To ensure mechanisms for efficient access to data and applications (deployed and made available in the DaPaaS Platform) from multi-devices (Web and mobile), taking into account that there are certain constraints, e.g. limited network bandwidth, memory, disk space, etc.

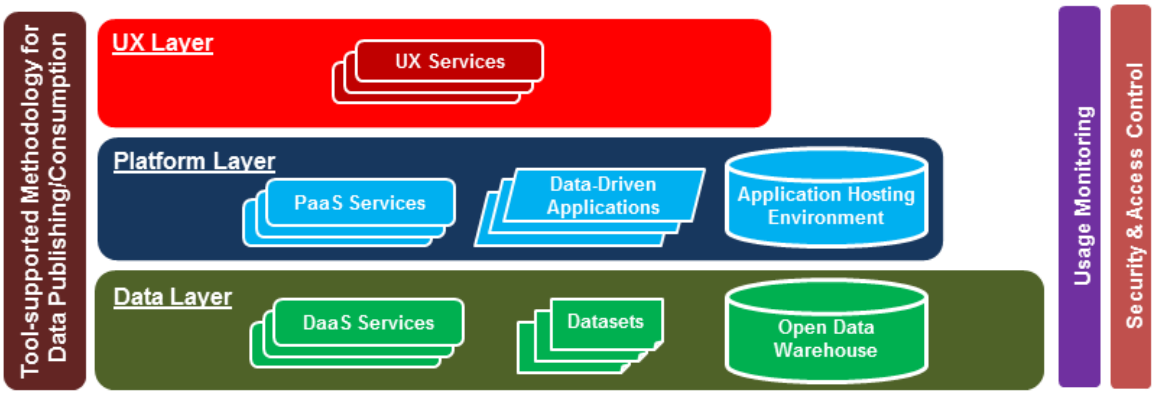


**Figure 1: High-level architecture of the DaPaaS Platform**

The rest of this document is organized as follows:

- Section 2 “Requirements Analysis for the UX Layer” provides a summary of the high-level requirements which the UX layer should support from the perspective of the key roles, and details a set of requirements on the visualization types the UX Layer should support;
- Section 3 “State of the Art Overview for Data Visualization in DaaS/PaaS Platforms” provides an analysis of existing solutions providing web and mobile UI, relevant technologies and standards;

- Section 4 “UI Layer Architecture” introduces the core capabilities of the UX Layer and the high-level architecture of the UX Layer;
- Section 5 "Relevant Visualization Tools and Libraries" provides an analysis of various 3rd party tools and libraries which may support the outlined technical architecture; and
- Section 6 "Summary and Outlook" summarizes this document and outlines some recommendations for the implementation of the first UX Layer prototype.

# 2 Requirements Analysis for the UX Layer

Deliverable D2.1 (DaPaaS Project, 2014) provides the complete list of business requirements for the overall DaPaaS Platform, and the descriptions of the key roles (actors) that will interact with it.

For the sake of completeness this section summarizes the key roles and their respective requirements which are relevant to WP3 and the focus of this deliverable respectively. For further details on the roles, the overall requirements and architecture, the reader is referred to Deliverable D2.1.

## 2.1 Key Roles in DaPaaS

The key roles involved in a typical DaPaaS context and their relationships to the platform, are illustrated in Figure 2. The roles are:

- The **DaPaaS Developer** responsible for implementing the DaPaaS software components and services for the integrated DaaS and PaaS environment.
- The **Instance Operator** is an administrator of deployed instance of DaPaaS software, i.e. the DaPaaS Platform.
- The **Data Publisher** has the goal of publishing data on the DaPaaS Platform so that it is available to 3rd party application developers and end user data consumers.
- The **Application Developer** develops data-driven applications that utilize the data hosted on the DaPaaS Platform. The applications are deployed and hosted in the DaPaaS Platform.
- The **End-Users Data Consumer** indirectly utilizes the hosted data via using the Web and mobile applications hosted on the platform.

The role of WP3 is to provide graphical user interfaces through which each of the roles outlined above can access various functionalities of the platform. As we are dealing with data and data-intensive applications which will be hosted on the platform, especially in a multi-device context, a key challenge to be addressed within the context of this WP is efficient access to data and applications (deployed and made available in the DaPaaS Platform) from multi-devices (Web and mobile), taking into account that in such context, there are certain constraints, e.g. limited network bandwidth, memory, disk space, etc.

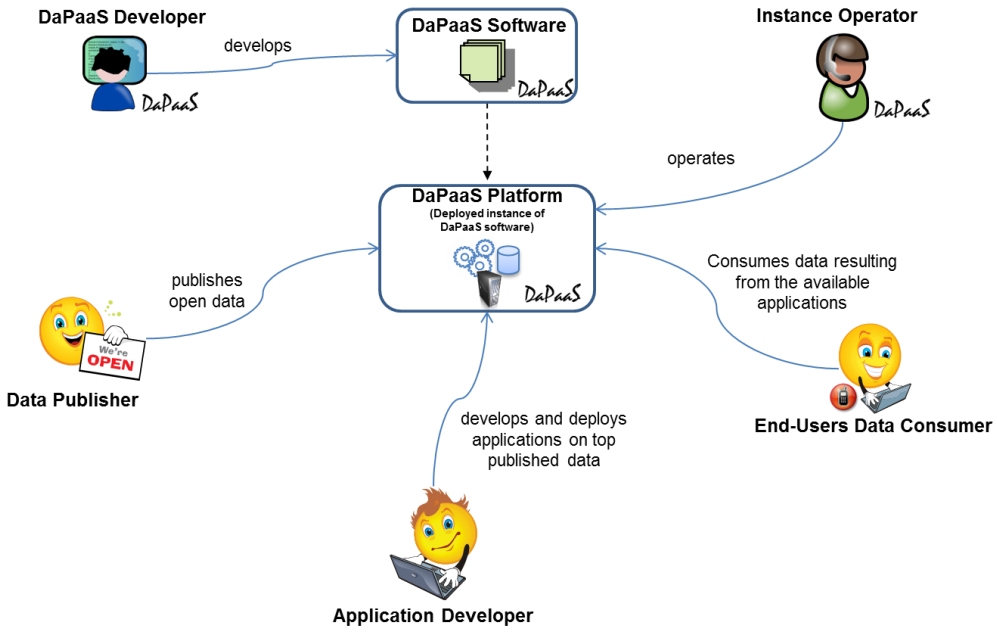


**Figure 2: Key roles/actors in DaPaaS**

## 2.2 Visualization Requirements for the UX Layer

Table 1 summarizes the DaPaaS platform requirements on visualization aspects, from the point of view of the key roles played in DaPaaS context. It is a requirement that each role (Instance Operator, Data Publisher, Apps Developer, and End-User Data Consumer) is supported by one or more graphical interfaces that provide access to the platforms functionality. The focus will primarily be on the visualization support for End-User Data Consumer for accessing data and date-intensive applications hosted on the platform. For a complete list of requirements for the DaPaaS Platform, the reader is referred to Deliverable D2.1.

**Table 1: Description of visualization requirements for DaPaaS Key Roles**

| ID | Name | Brief description |
|---|---|---|
| IO-06 | UI for Instance Operator | The Instance Operator shall be able to access the platform services through appropriate user interface (graphical and/or console). |
| DP-12 | UI for Data Publisher | The Data Publisher shall be able to access the DaaS services through appropriate user interfaces (graphical and/or console). |
| AD-07 | UI for Application Developer | The Application Developer shall be able to access the relevant DaaS and PaaS services through appropriate user interfaces (graphical and/or console). |
| EU-04 | Mobile and desktop GUI access | End-Users shall be able to access applications on both mobile and desktop devices, which require UX components to support both mobile and desktop users in an appropriate manner. The End-Users Data Consumers shall be able to access the relevant platform services, e.g., search for datasets, applications, run applications, visualize datasets, etc., through appropriate graphical user interfaces (GUIs), e.g., pie charts, time series and maps. |

The exact visualization types for the functionalities of components developed in the Data and Platform Layers will be decided once the components are developed. For now, we outline generic visualization types that will be supported by the UX Layer and which will be offered for the other components as they are developed.

According to the TDWI Report 2013 “Data Visualization and Discovery for Better Business Decisions”[1] the most commonly used data visualization types are: bar charts (95%), line chart (75%), pie charts (75%), tables, scatter plots. The UX layer will at least support these most common chart types, encapsulating them into widgets for data visualization. Table 2 outlines the requirements on the visualization types to be supported by the platform.

[1] http://download.1105media.com/pub/tdwi/files/TDWI_BPReport_Q313_DVIS_Web.pdf

**Table 2: Description of requirements for Visualization Types**

| ID | Name | Brief description |
|---|---|---|
| UI-01 | Cross platforms and mobile support | The data should be viewable on major browsers and platforms including mobile. HTML5/JS is required. |
| UI-02 | Support for bar and column charts | Bar chart is the most commonly used chart (according to the TDWI research – 95% penetration). The bar chart is the most appropriate chart type for comparing results. The column chart is a deviation of bar chart. The platform must support bar charts. |
| UI-03 | Support for line and area charts | Line chart is the second most popular chart type. This type of chart is relevant to display transition of data or change of data over time. The area chart is deviation of the line chart. The platform must support line chart. |
| UI-04 | Support for pie charts | The pie chart is the third most popular type of charts. The pie chart is most appropriate to display data composition. The platform must support pie chart. |
| UI-05 | Support for scatter plots and bubble charts | Scatter plot and bubble chart are the most convenient mechanism to show relationship between different data. Bubble chart is variation of scatter plot with 3rd variable. The platform must support scatter plot. |
| UI-06 | Support for tables | Tables are the most intuitive way to display multi-dimensional tabular data. The platform must support tables. |

# 3 State of the Art Overview for Data Visualization in DaaS/PaaS Platforms

In this section we review the relevant DaaS and integrated DaaS/PaaS platforms (that have been mentioned in deliverables D1.1 and D2.1) in terms of the visualization capabilities that they offer.

## 3.1 Microsoft Azure Marketplace

The Windows Azure platform provides a marketplace[2] for applications and data. Currently there are hundreds of apps, components, widgets and dashboards focused on management and visualization of different kind of data on the marketplace.

The apps are developed by the third parties and published on the marketplace, which provide monetization model for the app developers.

Most of the components and apps focused on data visualization are developed on Silverlight (Microsoft's preferred platforms for interactive UI), but some of the developers rely on HTML5 and support mobile devices.

According to the Azure development FAQ[3] there does not seem to be much data visualization support provided by the Azure platform itself:

> **"Are there data visualization tools available for Azure resident data collections?** Both Excel and Matlab running on the desktop can be used to visualize data stored on Windows Azure. More sophisticated local and remote visualization tools will be made available."

Application Developers are directed to e.g. Windows Azure Tools for Visual Studio[4]. There exists 3rd party development tools with data visualization components for Visual Studio, e.g. Infragistics Silverlight Controls[5], that can be used to develop applications for Windows Azure.

## 3.2 DataMarket

DataMarket collects publicly available data sources along with user uploaded data and normalizes all data into one format, allowing user to work with this data in similar manner, as well as compare different data set, combine data, visualize it, search, create reports and dashboard etc.

DataMarket supports 14 different chart types (line, relative line, stacked area, 100% stacked area, bar, stacked bar, 100% stacked bar, column, stacked column, 100% stacked column, table, choropleth maps, current values, and pie)[6], which can be used to create dashboards. Charts are based on HTML5 and can be viewed on every HTML5 compatible browser including on mobile devices.

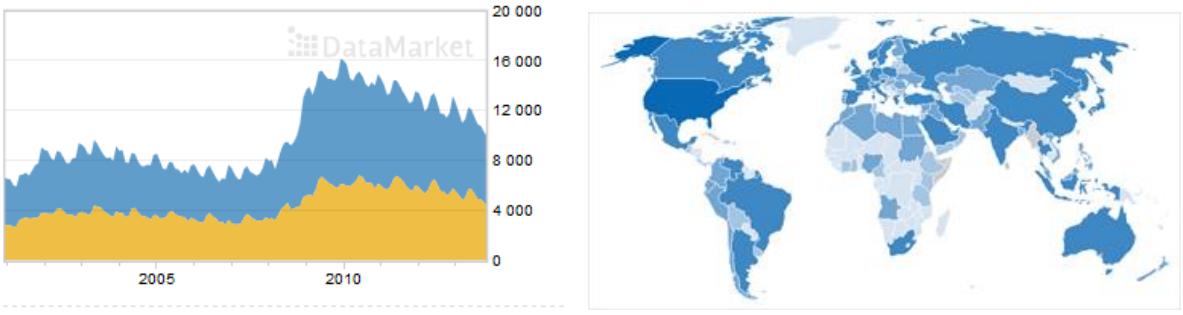


**Figure 3: DataMarket – Stack area chart (left) and choropleth map (right)**

[2] https://datamarket.azure.com/
[3] http://research.microsoft.com/en-us/projects/azure/faq.aspx
[4] http://msdn.microsoft.com/en-us/library/windowsazure/ff687127.aspx#Create
[5] http://www.infragistics.com/products/silverlight/
[6] http://datamarket.com/p/chart-types/

The DataMarket's Data Hub provides free access for data consumers to the basic features of the system, including charting and visualization and premium paid features for publishing data and embed them into enterprise systems.

## 3.3 Socrata

Socrata[7] is a platform focusing on Open Data and services. The Socrata Open Data Portal[8] allows users to create maps and charts:

- Interactive map from location data, or GIS files like Esri shapefiles, KML/KMZ files, using either Google Maps, Bing Maps or ESRI.
- Chart creation capabilities includes various chart types such as Area, Bar, Column, Donut, Line, Pie, Time Line, Tree Map and Heat Map.

How-to videos for creating a bar chart and a point map are provided on the Socrata Open Data Portal website (see Figure 4).

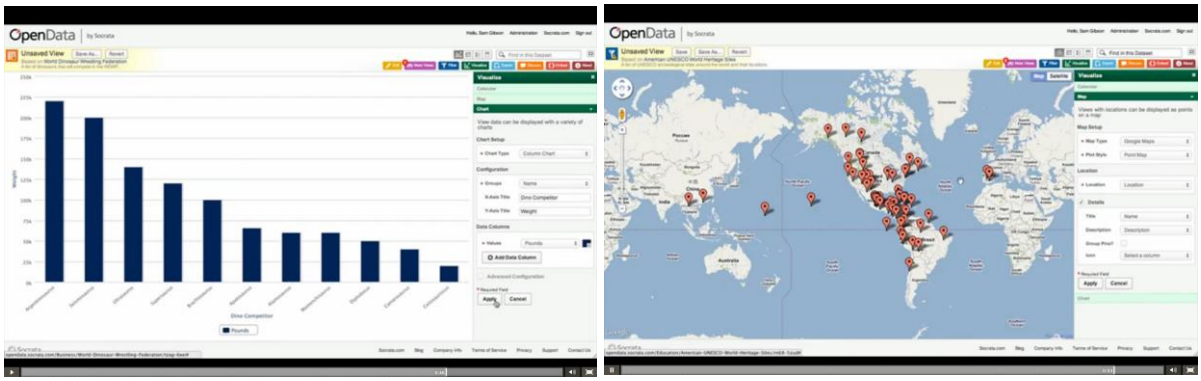

**Figure 4: Socrata – Bar chart map (left) and point map (right)**

## 3.4 LOD2

The LOD2[9] project (LOD2 Project, 2012) aims at providing an open source, integrated software stack for managing the complete lifecycle of Linked Data. For the Search/Browsing/Exploration part of the lifecycle the following tools are included:

- **Sig.ma:**[10] The sig.ma service was created as a demonstration of live, on the fly Web of Data mashup. Provide a query and Sig.ma will demonstrate how the Web of Data is likely to contain surprising structured information about it (pages that embed RDF, RDFa, Microdata, Microformats).
- **SemMap:**[11] An application for browsing and exploring geographical RDF data on a map.
- **CubeViz:** [12] CubeViz allows visualization of the Data Cube linked data representation of statistical data. It has support for the more advanced DataCube features, such as slices.
- **Facete:**[13] Facete is a spacial semantic browser application, with a focus on faceted browsing.

[7] http://www.socrata.com/
[8] http://www.socrata.com/open-data-portal/
[9] http://lod2.eu/
[10] http://sig.ma/?page=sigmaee
[11] http://wiki.aksw.org/Projects/SemMap
[12] http://aksw.org/Projects/CubeViz.html
[13] http://aksw.org/Projects/Facete.html

## 3.5 European Union Open Data Portal

The European Union Open Data Portal[14] provides an access to the open data produced by the institutions and other bodies of the European Union.

Along with the data portal, it provides various applications[15] for data visualization which are used to process and visualize datasets in the portal. The applications provide various data visualizations, including charts (bar, line, scattered plot), maps (geo data), dashboards, data comparison. The applications provide interactive access to the data where you can change various filtering criteria and update dashboards / charts / graphs. Most of the applications are based on HTML5 / JS technology so they are fully compatible with all browsers, including mobile.

The Digital Agenda Scoreboard[16] is one of the listed applications. It is a Web application that allows users to interactively create graphs to view the data for hundred indicators of the European information society, comparing progress across countries and over time.


**Figure 5: Digital Agenda Scoreboard Web application**

## 3.6 Datameer

Datameer[17] was founded in 2009 by some of the original contributors to Apache Hadoop (an open source framework processing large datasets). Datameer provides analytics software[18] on top of the Hadoop framework that allows integrating, analyzing and visualizing data.

Datameer provides an extensive library of data visualization widgets[19] that includes tables, graphs, charts, diagrams, maps, and tag clouds which enables users to create dashboards. In addition to simple dashboards, Datameer provides a solution called Business Infographics where data visualizations have no built-in constraints and users can drag and drop any widget, graphic, text or infographic element (see Figure 6). Datameer uses HTML5 supporting both desktop and mobile users.

[14] https://open-data.europa.eu/en/data/
[15] https://open-data.europa.eu/en/apps
[16] http://ec.europa.eu/digital-agenda/en/create-graphs
[17] http://www.datameer.com
[18] http://www.datameer.com/product/
[19] http://www.datameer.com/product/data-visualization.html

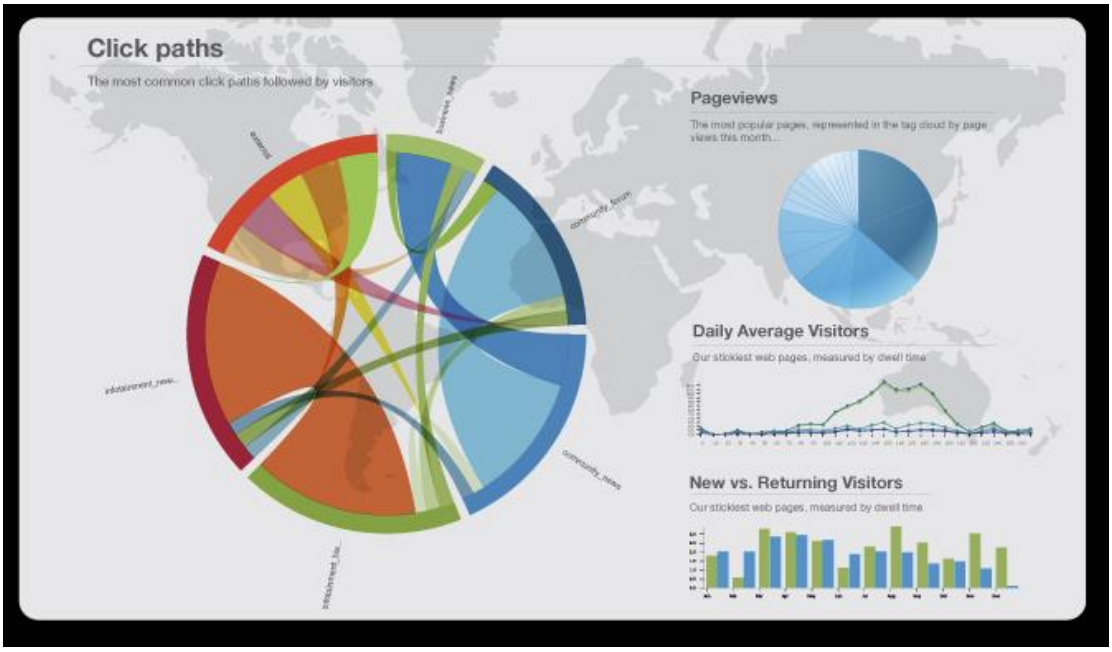


**Figure 6: Datameer – Business Infographics data visualization solution**

## 3.7 Splunk

Splunk[20] provides software designed to manage unstructured data generated by machines (Websites, applications, servers, networks, mobile devices, sensors and RFID assets). The Splunk Enterprise software product provides features for collecting and indexing any machine data, including the capability to handle massive live data streams, statistical analysis and real-time dashboards.

By default, Splunk creates dashboards using simple XML[21]. Developers can create and modify simple XML dashboards using Splunk's interactive editing tools without writing any simple XML code. Splunk provides a dashboard examples app[22] using simple XML (see Figure 7).

In addition, Splunk provides extensions for developing more advanced interactive visualization through the SplunkJS stack[23] and Django Web framework[24].

[20] http://www.splunk.com
[21] http://docs.splunk.com/Documentation/Splunk/latest/Viz/WebFramework
[22] http://apps.splunk.com/app/1603/
[23] http://dev.splunk.com/view/webframework-splunkjsstack/SP-CAAAESV
[24] http://dev.splunk.com/view/webframework-djangobindings/SP-CAAAEM6

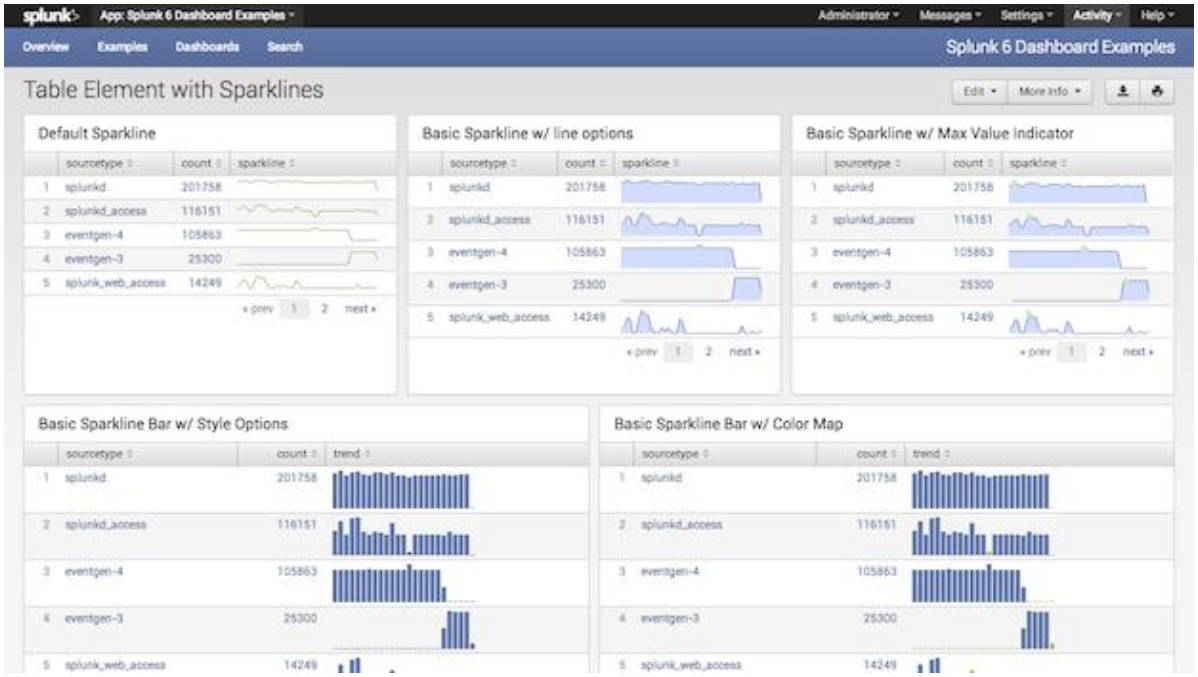


**Figure 7: Splunk – Dashboard examples app**

## 3.8 Tableau Software

Tableau Software[25] provides a set of interactive data visualization products focused on business intelligence, ranging from desktop to hosted solutions. Tableau offers a full set of capabilities that allows users to create visual analysis for data discovery, data visualization and dashboards[26] such as:

- **Big data analysis:** Visual analysis tools to investigate trends and outliers in big data;
- **Data discovery:** Investigate data at speed-of-thought, asking and answering questions as you go;
- **Mapping software:** Add "where" to your analysis for more insight, fast answers;
- **Business dashboards:** Drag and drop to create interactive dashboards, and then share in a browser (see Figure 8);
- **Data visualization:** A broad range of data visualization tools. Tableau provides a guide[27] for selecting the between 11 different types of visualizations (bar, line, pie, map, scatter plot, Gantt, bubble, histogram, bullet, heat map and highlight table).

Tableau Software provides a free, public data story telling application called Tableau Public[28]. It allows users to create and share interactive charts and graphs, stunning maps, live dashboards and fun applications in minutes, then publish anywhere on the Web (see Figure 9).

A key technology behind Tableau Public is the VizQL visual query language[29]. VizQL is a computer language for describing tables, graphs, charts, maps, time series, tables of visualizations and dashboards. It unifies all of these different visual representations into a simple language.

[25] http://www.tableausoftware.com
[26] http://www.tableausoftware.com/solutions/capabilities
[27] http://www.tableausoftware.com/learn/whitepapers/which-chart-or-graph-is-right-for-you
[28] http://www.tableausoftware.com/public/download
[29] http://www.tableausoftware.com/public/our-story

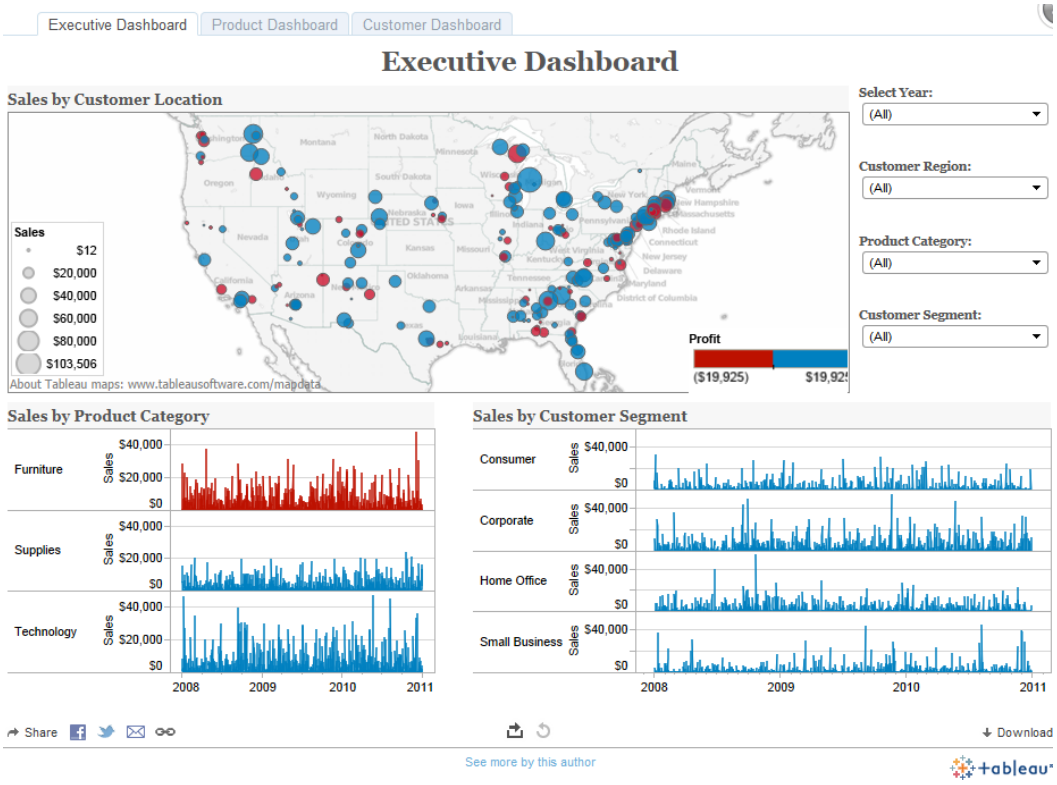


**Figure 8: Tableau – Example of business dashboard**

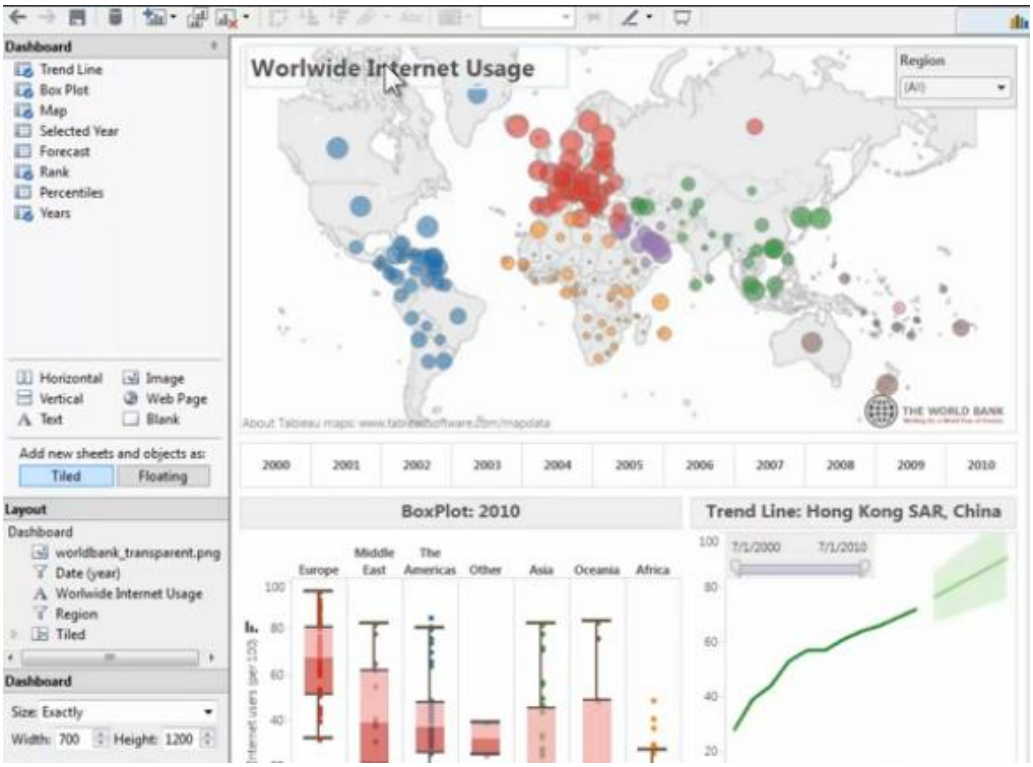


**Figure 9: Tableau Public**

# 4 UI Layer Architecture

In Section 1 and 2 above we introduced the UX Layer of the DaPaaS platform, together with visualization requirements. Based on these high-level requirements, this section outlines the "technical view" of the DaPaaS UX Layer with concrete capabilities and components supporting the identified requirements.

## 4.1 Functional Aspects

As the UX Layer has to deal with graphical widgets for various types of data visualizations and ensure mechanisms for efficient access to data from the graphical interfaces, the architecture of this Layer will have to support integration of graphical components / widgets, and components related to efficient data access. In the following we briefly introduce the components necessary to address the visualization aspects of the platform.

### 4.1.1 Graphical Widgets

Graphical widgets are reusable components that display data as charts, tables, etc., and can be easily customized and used to create dashboards, infographics or embed in Web pages. The widgets should be accessible both from desktop and mobile devices. The UX Layer will support the following widgets:

- Table widget – displays tabular data. This component is appropriate for use when multi-dimensional data need to be displayed.
- Bar chart widget – displays comparison of two or more datasets.
- Line chart widget – displays change of data over time.
- Pie chart widget – displays structure of data.
- Scatter plot – displays relation of elements.

### 4.1.2 Data Summarization

The UI interface, especially data consumer interfaces (including mobile), should provide means for easy data exploration and analysis, including dashboard and different data visualization techniques. The data consumer clients will not download entire datasets in order to display data on charts or dashboards. Data aggregation / summarization will be implemented on the server and only the minimal sets of required data for visualization will be transferred to the client.

### 4.1.3 Caching

Caching of query results is required in order to improve the UX Layer performance and scalability and reduce the overload of the back end components of the platform. Caching algorithms can be implemented on several levels:

- Caching most frequently used data;
- Caching API calls, eliminating need to make consequence call to the same API;
- Caching UX Layer response to the graphical widget, eliminating need to process data from the backend.

### 4.1.4 Notifications

The notifications component is used internally as a message bus between other components, providing effective way to subscribe for certain events and get notified when event happened. Events can trigger synchronization actions between internal components, such as updating data, updating chart, show report, etc. This will complement the data summarization functionality and act as a mechanism for exchanging data between the clients and the platform.

## 4.2 UI Layer Architecture & Components

Section 6.1 outlined the technical capabilities that will be implemented in the UI layer of the platform. This section outlines how these capabilities are mapped to concrete software components, as depicted in Figure 10 – the architecture of the DaPaaS UX Layer.

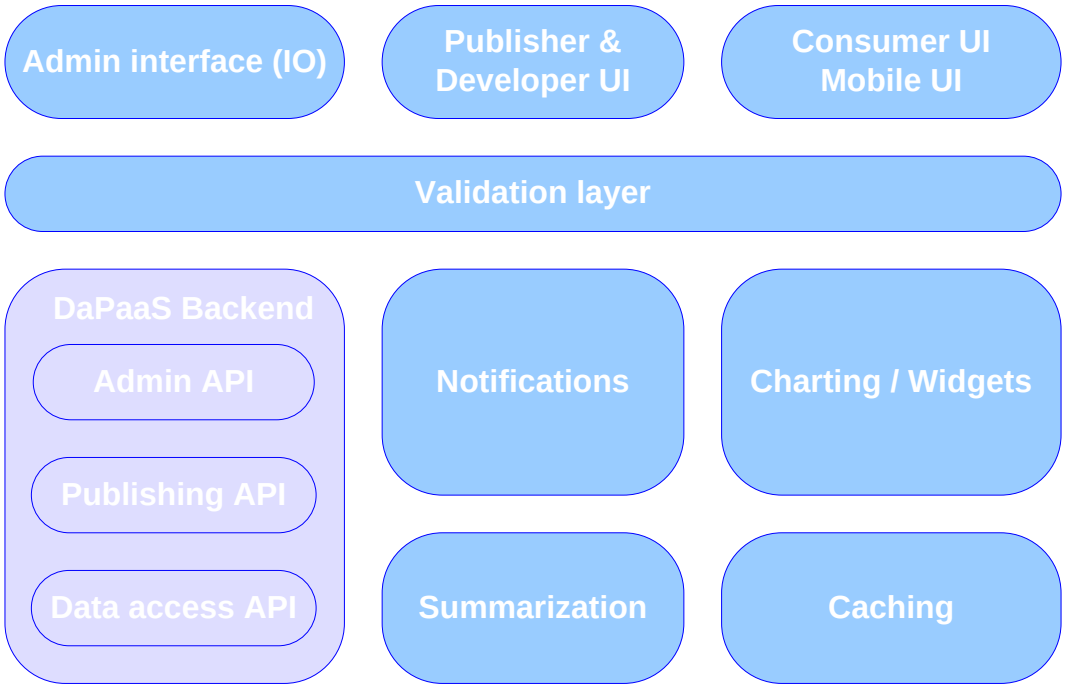


**Figure 10: UI Layer Architecture**

# 5 Relevant Tools

This section identifies tools that can be relevant to the development of UX Layer components. Due to specifics of some components we may need to develop them from scratch.

Summarization component requests data from the backend and aggregates it into small datasets that can be relevant to the selected visualization widget. Due to specifics of DaPaaS project this component needs to be developed from the scratch.

The Caching component is relevant for the data after summarization, and provides server-side caching capabilities for the processed data. Due to specifics of the implementation of caching, this component will be developed from scratch.

Widgets will display standard charts and can be implemented using support chart libraries which match the requirements for the UX Layer.

The rest of this section will review some of the visualization libraries and HTML5 libraries that can be used for UX Layer for DaPaaS Platform. With few exceptions, most of the frameworks that provide charting capabilities are focused only on visualization and does not provide any additional functionality. In order to provide reasonable comparison we have separated visualization frameworks from HTML5 frameworks.

## 5.1 Visualization Frameworks

As a part of Task 3.1 more than 30 popular visualization frameworks have been reviewed. Appendix A shows a table of reviewed frameworks with their attributes: supported chart types, features, supported browsers, etc.

Based on this review, the most relevant frameworks for the DaPaaS Platform are included in this section. The selection process includes libraries that are open source, free, supporting desktop and mobile devices, matching requirements for the outlined visualization types, with reasonable documentation, examples and support community, and are regularly maintained.

### 5.1.1 D3

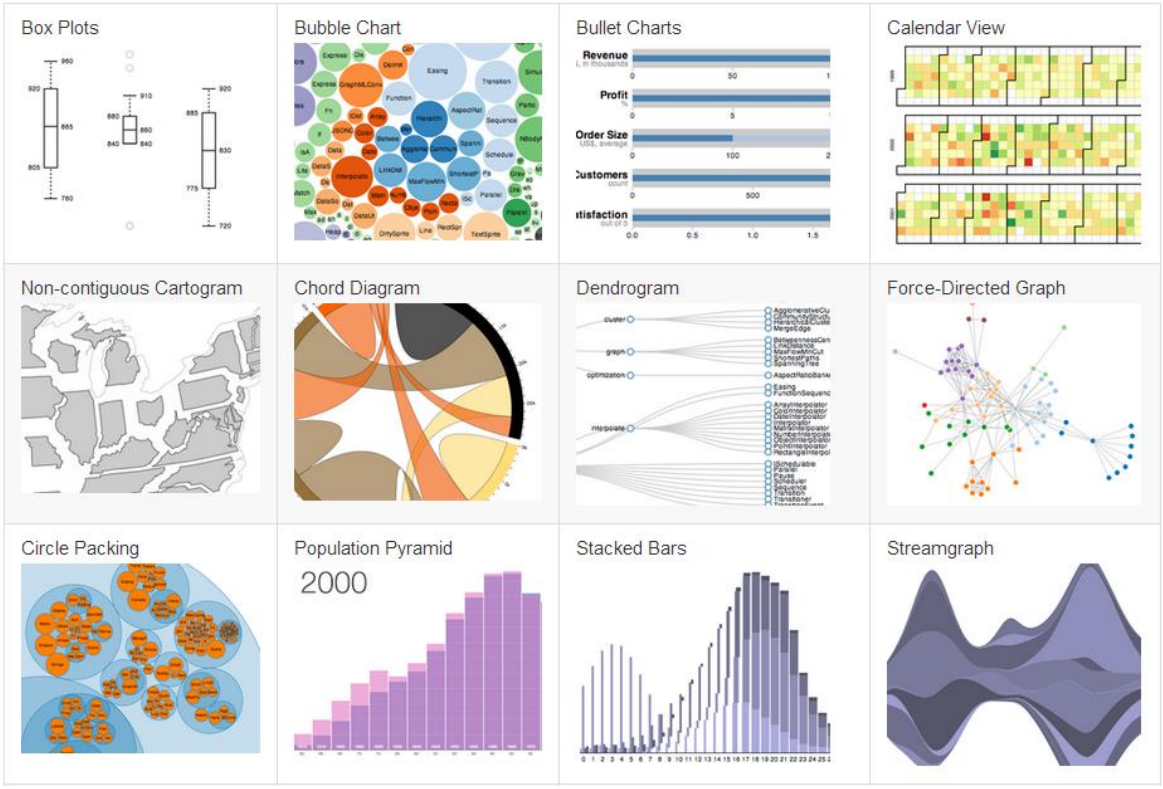


**Figure 11: D3 charting**

http://d3js.org

D3.js is a JavaScript library for manipulating documents based on data and data visualization library based on HTML, SVG and CSS. The framework provides quite extensive APIs not just for visualization but also for managing data driven documents and transforming them into HTML, XML or directly manipulate their content.

### Maintenance

The D3 library is quite mature, with good community, documentation and examples.

https://github.com/mbostock/d3/wiki/Gallery

https://github.com/mbostock/d3/wiki

### Licensing

D3 is free, open source JavaScript library, licensed under BSD.

### Accessibility

The D3 framework is quite extensive with many feature, but with steep learning curve. The leading time to start using framework is longer than with other visualization frameworks.

## 5.1.2 Flot

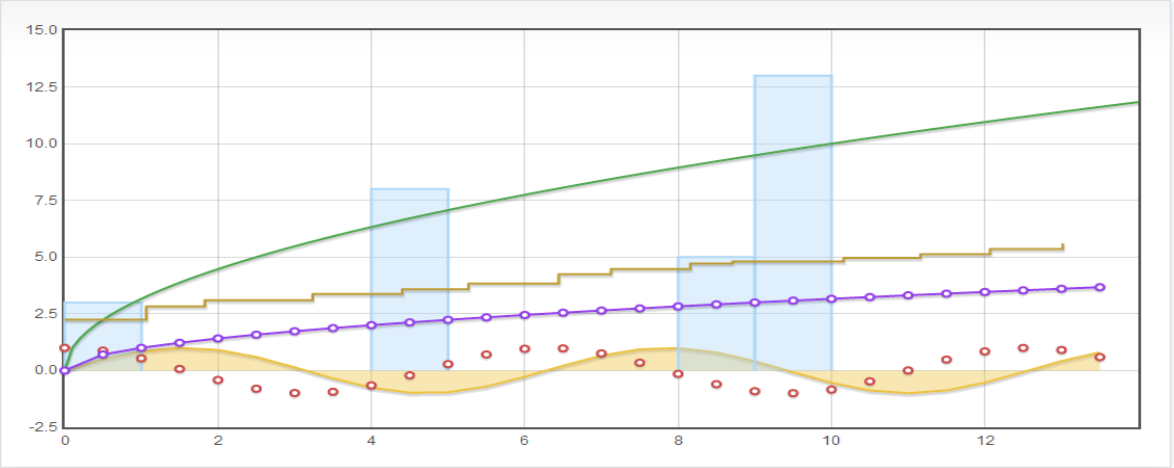


**Figure 12: Flot charting**

http://www.flotcharts.org

Flot is a JavaScript plotting library based on jQuery. The library supports all major types of charts and has quite good support for browsers, including mobile browsers. As the library is based on jQuery it can provide creation of interactive charts.

### Maintenance

The library's Website contains detailed documentation with lots of examples and plug-ins.

http://www.flotcharts.org/flot/examples

http://github.com/flot/flot/blob/master/API.md

### Licensing

Flot is free, open source JavaScript library, licensed under MIT.

### Accessibility

The library utilizes jQuery DOM framework and it has a less steep learning curve, especially for developers familiar with jQuery.

### 5.1.3 jqPlot

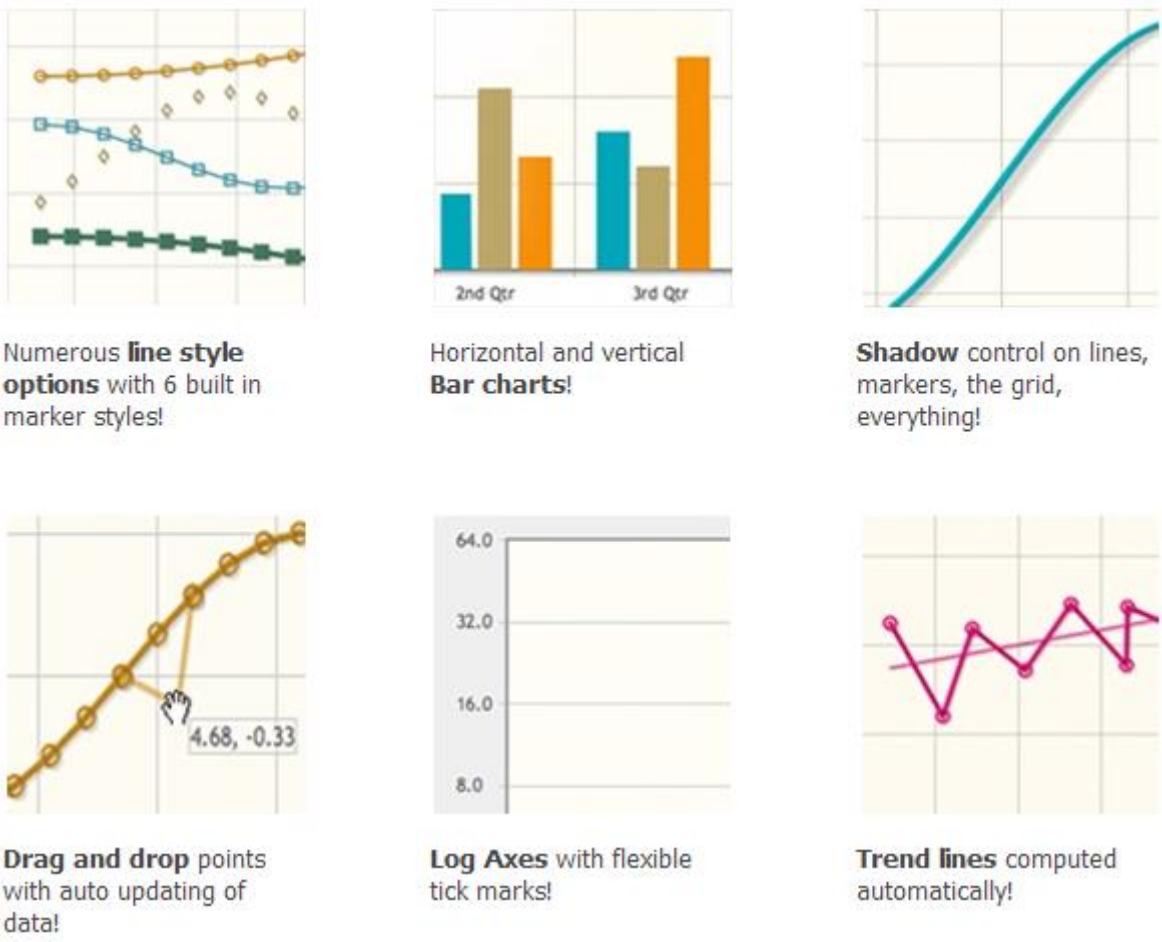


**Figure 13: jqPlot charting**

http://www.jqplot.com

jqPlot is another plotting library based on jQuery with good support of different charts, browsers and extendable APIs with plug-in architecture.

#### Maintenance

The library's Website contains detailed documentation along with examples and plug-ins.

http://www.jqplot.com/tests/

http://www.jqplot.com/docs/

#### Licensing

jqPlot is free, open source JavaScript library, licensed under MIT or GPL.

#### Accessibility

The library utilizes jQuery DOM framework and it has less steep learning curve, especially for developers familiar with jQuery.

## 5.2 Mobile UI Frameworks

### 5.2.1 jQuery

```
$.ajax({
  url: "/api/getWeather",
  data: {
    zipcode: 97201
  },
  success: function( data ) {
    $( "#weather-temp" ).html( "<strong>" + data + "</strong> degrees" );
  }
});
```

http://jquery.com/

jQuery is a feature-rich JavaScript library with extensive support for animations, event handling, Ajax and many other features. The library is quite mature and de facto standard for JS UI development.

#### Maintenance

The library's Website contains detailed documentation along with examples and plug-ins.

http://api.jquery.com/

http://learn.jquery.com/

#### Licensing

jQuery is free, open source JavaScript library, licensed under MIT.

#### Accessibility

The jQuery framework is quite extensive with many features and quite popular among UI developers. Due to popularity usually there is no leading time to start working with this framework.

### 5.2.2 Dojo

```
dojo.xhrGet({
  url: "/api/getWeather",
  handleAs: "json",
  load: function(response){
    dom.byId("weather").innerHTM = response;
  },
  error: function(err){
    console.log("error:", err);
  }
});
```

http://dojotoolkit.org/

Dojo is a JavaScript library that provides fast cross-browser and cross-platform development process with extensive HTML5 support. Dojo also provides capabilities for creating charts and 2D graphs.

#### Maintenance

The library's Website contains detailed documentation along with examples and plug-ins. There is a strong community behind the project.

http://dojotoolkit.org/documentation/

http://dojotoolkit.org/community

### Licensing

Dojo is free, open source JavaScript library, licensed under BSD.

### Accessibility

The Dojo framework is quite extensive with many feature, but with steep learning curve. The learning time to start using framework is longer than with other frameworks.

# 6 Summary and Outlook

This document provided an overview of the UX Layer of the DaPaaS platform, outlined a set of requirements for the UX Layer from the perspective of key roles, and the visualization types the platform should support. Furthermore, it provided an initial architecture design for the UX Layer and associated core components, provided a state-of-the-art overview of how relevant DaaS and integrated DaaS and PaaS solutions deal with data visualization, and surveyed relevant visualization frameworks relevant for the implementation of the UX Layer. Following the technology evaluation performed as part of this document, the following remarks are to be considered for the implementation phase of the UX Layer, with a particular focus on the Platform Layer:

- jQuery is the one of the most widely used libraries for client side scripting used all around the Web and obvious choice for creating dynamic Web 2.0 sites. There are a lot of plugins available for jQuery covering different aspects such as tabs, accordions, dialog boxes, etc. This library is an obvious choice for creating Web interfaces for the DaPaaS platform.
- Dojo is similar to the jQuery library with good support for creating different visual interface elements, such as tabs, dialogs, etc. The library has strong community behind it and it is second most used client side scripting library for Web applications. This library is the second best choice for creating Web interfaces for the DaPaaS platform. Dojo has some advantages over jQuery regarding the support for charts – there is charting functionality implemented in the library. Unfortunately the internal charting functionality is not as strong as other solutions mentioned in this document.
- D3 is a quite sophisticated library with excellent support for charts, matching DaPaaS requirements. It is open source, has good active community supporting it and lot of examples. The library is an excellent choice for generating dynamic charts. The main disadvantage of D3 is that the development effort needed to create widgets based on this library is significant compared to other alternatives.
- jqPlot and Flot are excellent alternatives for D3. Even though these two frameworks provide less functionality than D3, they match the requirements outlined in this document and can implement all the required functionality related to visualization types.
- We need further investigation concerning the choice of jqPlot/Flot vs D3 in order to select the best alternative for DaPaaS based on development efforts, project requirements, and future development of the project.
- The Caching and Summarization components shall be developed from the scratch to meet project specifics.

# 7 Appendix A: Review of Data Visualization Frameworks

## 7.1 Frameworks

| | | Open source | Latest version | Trial and Prices |
|---|---|---|---|---|
| amCharts | http://www.amcharts.com/ | No | 3.X | Free with watermark $99 (single website) |
| arcadiaCharts | http://www.arcadiacharts.com/ | No | 1.0.2 | Free for non commercial use<br>$ 89 (single website) - $ 899 (OEM) |
| CanvasJS Charts | http://canvasjs.com/ | CC license 3.0 | 1 | Free for non-commercial use $299+ for commercial license |
| D3.js | http://d3js.org/ | BSD License | 2.10.2003 | Free under BSD |
| dhtmlxChart | http://www.dhtmlx.com/docs/products/dhtmlxChart/index.shtml | GNU GPL | 2.6 Build 100928 | Free under GNU GPL, $49 |
| Dojo (dojox/charting) | http://dojotoolkit.org/ | BSD, AFLv2 | 1.8 | Free |
| Ejschart | http://www.ejschart.com/ | No | 2.3 | Free / $100 / $250 / $1000 |
| Elycharts | http://elycharts.com/ | MIT License | 2.1.2004 | Free |
| Flot | http://www.flotcharts.org/ | MIT License | 0.8.1 (may 2013) | Free |
| flotr2 | http://www.humblesoftware.com/flotr2/ | MIT License | | Free |
| Google Chart Tools | https://developers.google.com/chart/ | No | | Free |
| gRaphaël | http://g.raphaeljs.com/ | MIT License | 0.5.0 | Free (you can donate) |
| Highcharts | http://www.highcharts.com/ | CC by-nc 3.0 | 1 | Free for non commercial use<br>$ 80 (single website) - $ 2000 (10 developers license) |
| jqChart | http://www.jqchart.com/ | No | | $299 |
| jqPlot | http://www.jqplot.com/ | MIT, GPL v2 | 2013 | Free |
| JSCharts | http://www.jscharts.com/ | No | 3 | $ 39 - $ 149<br>Free with watermark |
| JSXGraph | http://jsxgraph.uni-bayreuth.de/wp/ | LGPL | 0.94 | Free |
| KendoUI DataViz | http://www.telerik.com/kendo-ui-dataviz | No | Q1 2013 | $ 399 |

| | | | | |
|---|---|---|---|---|
| Morris.js | http://www.oesmith.co.uk/morris.js/ | BSD | 0.4.1 | Free |
| nvd3 | http://nvd3.org/ | Apache 2.0 | | Free depending on Apache 2.0 |
| Protovis | http://mbostock.github.io/protovis/ | BSD License | 3.3.2001 | Free |
| RGraph | http://www.rgraph.net/ | No | 2012 | Free for non-commercial (CreativeCommons) License for commercial use. |
| Rickshaw | http://code.shutterstock.com/rickshaw/ | Yes | 2012 | Free of charge with copyright attribution |
| Sencha Touch Charts | http://dev.sencha.com/deploy/touch-charts-rc/ | No | | Free under GPLv3 license; $999 commercial license |
| TeeChart | http://www.steema.com/teechart/html5 | No | 2012 | Free for non commercial use.<br>$129 commercial license ( 1developer + 1 server install + 1 year support subscription) |
| zingchart | http://www.zingchart.com/ | No | 2010 | Free with watermark Single Domain Package : $249.00 Discounted Multi-Domain Package : $999.00 SaaS and OEM Pricing Available |
| Shield UI Charts | https://www.shieldui.com/products/chart | No | 1.4.2002 | $299 |
| SVGware | http://www.svgware.com/ | No | 2.6 (July 2013) | Free |
| Reportivo.com | http://reportivo.com/ | | | Free |

## 7.2 Supported Chart Types

| | Graphic technology | Area | Bar | Bub-ble | Line | Pie | Scat ter | Splin e | Spar kline s | Can-dle-stick | Donut | Node / Edge graph | Other charts |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| amCharts | SVG<br>VML for old IE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | | Gauges, Radar, Polar, Step line, Step without Risers, OHLC, area range, Donut, Funnel, Waterfall, Bullet, XY, Maps are available as additional package |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| arcadiaCharts | Canvas | No | Yes | No | Yes | Yes | | No | | No | Yes | | |
| CanvasJS Charts | CanvasJS | Yes | Yes | Yes | Yes | Yes | Yes | Yes | | No | Yes | | Bubble Chart |
| D3.js | SVG | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | - | Yes | Yes | D3.js is a drawing library, and not just a chart library. You can make virtually any visualization or graph given time. |
| dhtmlxChart | Canvas | Yes | Yes | No | Yes | Yes | No | Yes | Yes | No | Yes | | |
| Dojo (dojox/charting) | SVG<br>Canvas<br>VML<br>Silverlight | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No | | Bubble, Candlestick (OHLC), Spider. Other Dojo modules provide as well TreeMap, Gauges etc... |
| Ejschart | Canvas<br>SVG<br>VML | Yes | Yes | No | Yes | Yes | Yes | - | - | Yes | Yes | | f(x), Gauge, Donut, alarm, candle stick, step series, over under, open high low, error series, stacked bar, trend, and floating bar |
| Elycharts | SVG | Yes | Yes | No | Yes | Yes | No | Yes | Yes | No | Yes | | Funnel |
| Flot | Canvas | Yes | Yes | Yes | Yes | Yes | Yes | Yes | | Yes | Yes | | Bubbles, Gantt, Pyramid, Spider |
| flotr2 | Canvas | Yes | Yes | Yes | Yes | Yes | Yes | No | | Yes | No | | Bubble, radar |
| Google Chart Tools | SVG | Yes | Yes | No | Yes | Yes | Yes | No | No | Yes | No | | Geo chart, table, gauge, tree map |
| gRaphaël | SVG | Yes | Yes | No | Yes | Yes | No | No | No | No | No | | |
| Highcharts | SVG | Yes | Yes | Yes | Yes | Yes | Yes | Yes | | Yes | Yes | | |
| jqChart | Canvas | Yes | Yes | Yes | Yes | Yes | Yes | Yes | | Yes | No | | Bubble, radar, polar |
| jqPlot | Canvas | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | | |
| JSCharts | Canvas | No | Yes | No | Yes | Yes | No | No | | No | No | | |
| JSXGraph | SVG | No | Yes | No | Yes | Yes | No | Yes | | No | No | | Math... |
| KendoUI DataViz | SVG | Yes | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | | Linear Gauge, Radial Gauge, Bubble, Bullet, Donut, Scatter, Stock |
| Morris.js | SVG | Yes | Yes | No | Yes | No | No | Yes | No | No | Yes | | |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| nvd3 | SVG | Yes | Yes | Yes | Yes | Yes | Yes | Yes | | No | Yes | | Bullet chart |
| Protovis | SVG | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | | TreeMap, Node links |
| RGraph | Canvas | Yes | Yes | Yes | Yes | Yes | Yes | No | No | No | Yes | | Gauge, Funnel, Waterfall |
| Rickshaw | SVG | Yes | Yes | No | Yes | No | Yes | Yes | | No | No | | |
| Sencha Touch Charts | Canvas | Yes | Yes | No | Yes | Yes | Yes | Yes | No | No | No | | |
| TeeChart | Canvas | Yes | Yes | Yes | Yes | Yes | Yes | Yes | | Yes | Yes | | Horizbar, SmoothLine, Donut, HorizArea, Bubble, Candle (OHLC) |
| zingchart | Canvas<br>SVG<br>VML<br>Flash | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | | Bullet, Chord, Funnel, Gauge, Grid, Maps, Pareto, Piano, Radar, Rank-flow, Stock, Treemap, Venn, WordCloud |
| Shield UI Charts | SVG<br>VML | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | | Yes | | Range Bar/Area/SplineArea, Polar Bar/Area/Spline/Scatter, Stepline, Steparea |
| SVGware | SVG | Yes | Yes | Yes | Yes | No | Yes | No | No | No | No | | heat map; error bars; linear and logarithmic scales; |
| Reportivo.com | | Yes | Yes | | Yes | Yes | Yes | Yes | | | Yes | | Range Bar/Area/Spline Area, Polar Bar/Area/Spline/Scatter/Step-line/Steparea |

## 7.3 Additional Chart Features

| | Ability to zoom in and out of charts | Annotations on the chart | Combination of charts | Data labels | Date-time axis | Dynamic charts | Export files | External Data Loading | Interactive (responds to mouse hover/click) | Print | Text Rotation for Labels |
|---|---|---|---|---|---|---|---|---|---|---|---|

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| amCharts | Yes | Yes | Yes | Yes | Yes | Yes | Yes PNG, JPG, SVG, PDF | | Yes | Yes | Yes |
| arcadiaCharts | | | Yes | | | Yes | | | Yes | | |
| CanvasJS Charts | Yes | | Yes | Yes | Yes | Yes | | | Yes | | Yes |
| D3.js | Yes | | Yes | Yes | Yes | Yes | | | No | | Yes |
| dhtmlxChart | No | Yes | No | Yes | No | Yes | No | Yes | No | No | Yes With CSS |
| Dojo (dojox/charting) | Yes | No | Yes | - | -Feasible with custom code | Yes | Yes SVG | Yes | No | Yes | Yes |
| Ejschart | Yes | Yes | Yes | Yes | Yes | Yes | - | Yes | Yes | Yes | Yes |
| Elycharts | No | No | No | Yes | No | Yes | No | No | Yes | Yes | Yes |
| Flot | Yes | Yes | Yes | Yes | | Yes | No | Yes | Yes | No | |
| flotr2 | Yes | Yes | Yes | | Yes | Yes | Yes PNG, JPG | No | Yes | No | Yes |
| Google Chart Tools | No | No | Yes | No | Yes | No | No | No | Yes | No | No |
| gRaphaël | No | No | No | Yes | No | No | No | No | Yes | No | No |
| Highcharts | Yes | No | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| jqChart | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | | Yes |
| jqPlot | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | - | Yes |
| JSCharts | No | No | Yes | Yes | No | No | No | No | No | No | No |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| JSXGraph | No | | Yes | Yes | Yes | Yes | | Yes | Yes | | No |
| KendoUI DataViz | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Morris.js | No | No | No | No | Yes | | No | No | Yes | No | No |
| nvd3 | Yes | Yes | Yes | Yes | | Yes | | | Yes | | |
| Protovis | Yes | Yes | Yes | Yes | Yes | Yes | No | Yes | No | | Yes |
| RGraph | No | No | No | No | No | No | - | Yes | Yes | | |
| Rickshaw | Yes | | | Yes | | | | | Yes | | |
| Sencha Touch Charts | | | | | | | | | Yes | | |
| TeeChart | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | | Yes |
| zingchart | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Shield UI Charts | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| SVGware | Yes | Yes | Yes | Yes | Yes | Yes | Yes | - | Yes | Yes | |
| Reportivo.com | Yes | Yes | | Yes | Yes | | Yes | Yes | Yes | Yes | Yes |

## 7.4 Browser Support

| | Fire-fox | IE | Chrome | Safari | Opera | iPh-one | iPad |
|---|---|---|---|---|---|---|---|
| amCharts | Yes | Yes 6.0+ | Yes | Yes | Yes | Yes | Yes |
| arcadiaCharts | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| CanvasJS Charts | Yes | Yes 9+ | Yes | Yes | Yes | Yes | Yes |
| D3.js | Yes | Yes 9+ | Yes | Yes | Yes | Yes | Yes |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| dhtmlxChart | Yes 1.0+ | Yes 6.0+ | Yes | Yes 3.0+ | Yes 9.0+ | Yes | Yes |
| Dojo (dojox/charting) | Yes 3.6+ | Yes 6+ | Yes | Yes | - | Yes | Yes |
| Ejschart | Yes 1.5+ | Yes 6.0+ | Yes | Yes 3.1 | Yes 9+ | Yes 1+ | Yes |
| Elycharts | Yes 3.0+ | Yes 6.0+ | Yes 5.0+ | Yes 3.0+ | Yes 9.5+ | Yes | Yes |
| Flot | Yes | Yes 6.0+ | Yes | Yes | Yes | | Yes |
| flotr2 | Yes | Yes 6.0+ | Yes | Yes | | Yes | Yes |
| Google Chart Tools | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| gRaphaël | Yes 3.0+ | Yes 6.0+ | Yes 5.0+ | Yes 3.0+ | Yes 9.5+ | | |
| Highcharts | Yes | Yes 6.0+ | Yes | Yes | Yes | Yes | Yes |
| jqChart | Yes | Yes 6.0+ | Yes | Yes | Yes | Yes | Yes |
| jqPlot | Yes | Yes 7.0+ | Yes | Yes | Yes | Yes | Yes |
| JSCharts | Yes 1.5+ | Yes 8.0+ | Yes 10+ | Yes 3.1+ | Yes 9+ | Yes 1.0+ | |
| JSXGraph | Yes 2.0+ | Yes 6.0+ | Yes | Yes 3.0+ | Yes | Yes | Yes |
| KendoUI DataViz | Yes | Yes 7+ | Yes | Yes | Yes | Yes | Yes |
| Morris.js | Yes | Yes 6.0+ | Yes | Yes | Yes | Yes | Yes |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| nvd3 | Yes | - IE 9, IE8 requires Aight | Yes | Yes | Yes | Yes | Yes |
| Protovis | Yes | No | Yes | Yes | | Yes | Yes |
| RGraph | Yes | Yes 9+ | Yes | Yes | Yes | Yes | Yes |
| Rickshaw | Yes | Yes 9+ | Yes | Yes | Yes | Yes | Yes |
| Sencha Touch Charts | | | | | | Yes | Yes |
| TeeChart | Yes | Yes 9.0+ | Yes | Yes | Yes | Yes | Yes |
| zingchart | Yes | Yes 6.0+ | Yes | Yes | Yes | Yes | Yes |
| Shield UI Charts | Yes | Yes 5.0+ | Yes | Yes | Yes | Yes | Yes |
| SVGware | Yes | Yes | Yes | | Yes | Yes | Yes |
| Reportivo.com | Yes | Yes | Yes | Yes | Yes | Yes | Yes |