CUSTOMIZABLE VISUALIZATIONS WITH FORMULA-LINKED BUILDING BLOCKS

Mohammad A. Kuhail and Soren Lauesen
Software Development Group, IT University of Copenhagen, Rued Langgaards Vej 7, Copenhagen, Denmark

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Abstract: One approach to visualization construction is to use complex blocks (widgets) that are tailored for specific visualizations, and customize the visualizations by setting the properties of the widgets. This approach allows fast and easy visualization construction but falls short if the user wants different appearance or behaviour than what the widgets support. Another approach is to combine primitive graphical elements using traditional programming or visualization toolkits. Traditional programming allows high customizability, but it is time consuming and hard to develop advanced visualizations. Visualization toolkits allow easier visualization creation in some cases, but customization and interaction are tedious. As an alternative, we developed uVis visualization tool that uses spreadsheet-like formulas to connect building blocks. uVis formulas can refer to building blocks and database tables. We created several advanced visualizations, and compared our approach against others. Evaluation shows that our approach improved customizability.

1 INTRODUCTION

Visualizations show data by size, color, shape, and orientation. As users view and interact with visualizations, they analyze data and derive insight such as patterns, trends, clusters, and outliers (Spense, 2007); (Meirelle, 2011). The exploratory nature of data analysis requires that visualizations support users in finding their way through data by interacting with the visualization elements (Stolte and Hanrahan, 2000). Ideally, every visual element that makes the visualization is able to display information when needed and disappear when unneeded on user command (Ware, 2004).

Some visualization widgets allow easy and quick visualization creation but do not support the customization of each individual building block. Some low-level Graphics APIs together with traditional programming allow the customization of individual building blocks. However, this could be tedious and time consuming. Moreover, this approach is not accessible to *designers*, visualization creators with limited IT skills.

Some visualization toolkits such as prefuse and Protovis provide useful abstractions for visualization, but they do not support easy access to relational data, and visualization creators are required to have a solid programming background to obtain high customization or interactivity.

To achieve a high level of customization, a visualization needs to broken into basic building blocks whose properties can depend on data. Hence, we developed *uVis*, a tool with customizable building blocks suited for visualization construction. These blocks have *properties*, *events,* and *functions*, and can create *local data tables*.

We constructed several advanced visualizations using *basic building blocks* linked by spreadsheet-like formulas. To further speed up the development without sacrificing customizability, we designed *composite blocks* that generate and link several basic blocks that are still customizable.

To evaluate our approach, we created a custom visualization with uVis and a popular visualization tool, and compared customizability.

2 SOLUTION

The main goal of our solution is to support designers with limited IT skills to design customizable visualizations. To increase designer productivity, we wanted to combine the convenience of widgets and the customizability of basic blocks. Further, we wanted to support the visualization of relational data. To meet all these goals, we developed uVis building blocks and formulas. The building blocks are the visual elements that make up the visualization, and based on data, the formulas customize the appearance and behaviour of the blocks.

2.1 uVis Building Blocks

uVis building blocks are the elements that make up a visualization. They can be basic such as `TextBox`, `Icon`, `Label`, and `Canvas` or composite such as `ComboBox` (figure 1). The latter can be made of a combination of the formers. Blocks have built-in, properties, designer properties, and event handlers.

Built-in Properties customize the block appearance. As an example, a `TextBox` has `Top`, and `Left` properties that customize position. `DataSource` specifies how many block instances to create, and bind these instances to data rows. *Designer properties* are added by the designer to retain data. For instance, a designer might write a complex formula in a designer property and refer to it from other properties rather than repeating it.

Block behaviour is defined by event handlers. *Events* are triggered on mouse and keyboard user actions. Event statements specify what happens when an event occurs. For instance, a designer may specify a box to show up upon clicking a visual element in a graph.

With present tools, most of the properties have a fixed value. For instance, the back colour of a specific label can be set blue, and it can be positioned at the top left of the screen. To make these properties depend on data, some programming is needed. With uVis, each property can be customized by a formula that can refer to other properties and data. When a property value changes, formulas that refer to it automatically update the values of properties they customize. In this way the label back colour can depend on or more fields in the data base and properties in other blocks.

2.1.1 uVis Basic Building Blocks

uVis basic building blocks provide minimal functionalities, and can be used in many visualizations.

uVis provides several kinds of basic blocks. We explain them below.

Standard Input Blocks: Rather than designing all blocks from scratch, we use standard `.NET` input controls such as `TextBox` and `Button`.

Shapes: We designed a number of primitive shapes such as `Line`, `Ellipse`, and `Box` based on `GDI+` drawings, but enabled them to function as independent visual objects that receive mouse and keyboard events.

Inspired by Cleveland (1985), we provide glyphs such as triangles and stars. We also provide shapes that are commonly used in visualizations. For instance, a `Curve` block connects several points. However, the individual points are defined separately, and they connect themselves to the curve. This allows both curves and individual points to be customizable. The `Tension` property of a curve specifies how the curve bends through the coordinates of the connected objects.

2.1.2 uVis Composite Building Blocks

Composite building blocks comprise several basic blocks and have a few properties that can automatically specify properties of the basic blocks. The designer can still customize the properties of the individual basic blocks. Hence, visualization construction is sped up and simplified without compromising customizability. As an example, figure 1 shows a `ComboBox` that shows a list of patient names.

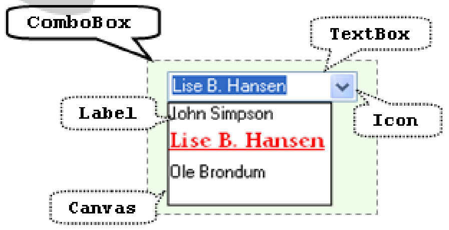


Figure 1: uVis ComboBox, a composite block. Comprised blocks are illustrated with dotted callouts.

To create the `ComboBox`, the designer first set a few properties of the `ComboBox` that allowed the block to refer to data and customize the general appearance. As a result, `ComboBox` generated several basic blocks (`Label`, `Canvas`, `Icon`, and `TextBox`), and automatically specified them. The designer set a few properties of the generated `Label` block to customize the appearance of the second patient name (Lise B. Hansen).

2.2 uVis Formulas

Each block property may have a formula. Formulas specify how to compute the property value for the block. They are declarative and correspond to spreadsheet formulas. Designers can customize the appearance and behaviour of visualization blocks with these formulas. They can refer to data fields in database tables and local tables, properties and functions of blocks. Rather than specifying one block at a time, uVis formulas can specify multiple block instances that are related to a data source. Let us look at an example.

Example – Creating a custom pie chart with uVis. Figure 2 shows a custom pie chart showing monthly visits and views of a website. Pie slice angles represent monthly visits of the website, and the radii represent monthly views. When the end-user clicks a pie slice, a message showing the visits and views in numbers shows up. The data behind the visualization resides in a database table `Statistics` with fields `views`, `visits`, `month`, and `year`.

uVis Development Environment. To create a custom pie chart, the designer dragged a `PieSlice` block from the toolbox, and dropped it in the design panel. A property grid showing the PieSlice default property values showed up.

The uVis environment is a what-you-see-is-a what-you-get (WYSIWYG) environment. Thus, the designer gets an immediate visual feedback in the design panel as he specifies the property formulas.

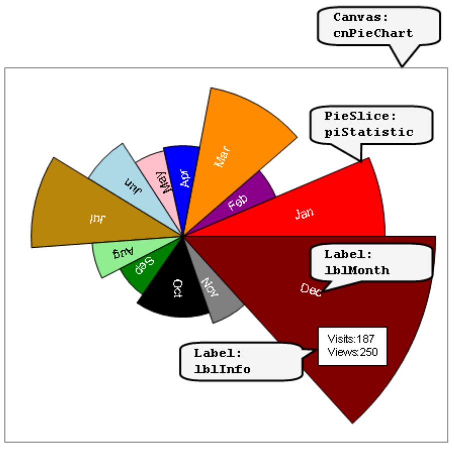


Figure 2: A custom pie chart representing the monthly visits and views of a website.

Multiple Instances per Block. To create `PieSlice` blocks representing the monthly statistics, the designer specified the `DataSource` of block `piStatistic` (of type `PieSlice`) in this way.

```
  PieSlice: piStatistic
DataSource: Statistics where year=2010
```

uVis translates the `DataSource` formula into an SQL statement, retrieves the corresponding record set from the database and creates one block instance for each row in the record set. Each instance is bound to a row. Hence, the instance can access the field values of the row.

Dynamic Formulas – Customizing individual block instances. To let the angle of pie slices show monthly visits, the designer specified `SweepAngle` in this way.

```
  SweepAngle: 360*visits/SUM(visits)
```

The `SweepAngle` formula refers to `visits`, which is a field in the table `Statistics`. uVis evaluates it for each `piStatistic` instance. `SUM(visits)` calculates the total monthly visits in the retrieved records. The result of the `SweepAngle` formula is the angle measured in degrees.

To align the pie slices next to each other around a circle, the designer specified StartAngle in this way.

```
  StartAngle: index=0? 0 : Me[index-
1]!StartAngle+Me[index-1]!SweepAngle
```

`StartAngle` means that if it is the first pie slice, the value is 0, for the rest of the slices the value is the previous slice's end angle. `Me` is the current instance, and `Index` is the current instance's index in the record set. Thus, `Me[index-1]` is the previous block instance. The formula retrieves the previous instance's `StartAngle` and `SweepAngle` by means of the `!` operator, which refers to properties.

To let the pie slice radius represent the monthly views, the designer wrote this formula.

```
  OuterRadius: 200*views/ MAX(views)
```

`MAX(views)` calculates the maximum monthly views in the retrieved rows. The result is the radius measured in pixels and proportional to the area. The longest radius is 200 pixels long.

3 EVALUATION

To evaluate our approach, we created a custom pie chart using a popular visualization tool, Protovis and evaluated how much it rates against uVis in these dimensions.

1. **Customizability.** To what extent a designer can customize the visual elements of a visualization.
2. **Accessibility.** To whom is the solution accessible? Can a designer make the visualization?

To create the custom pie chart in figure 2, Protovis uses a “`Wedge`” block (pie slice), and customizes its properties dynamically using anonymous functions. The programmer retrieved the data in a multi-dimensional array form. However, rather than using a where clause to filter it (e.g. get statistics where the year=2010), the programmer filtered it using a for loop. The programmer customized pie slices’ angles and radii according to data using dynamic properties. Protovis has a default implementation that calculates the end angle of previous pie slice automatically. In uVis, we did it by referring to the previous instance’s start angle and sweep angle. Such referencing is not possible in Protovis.

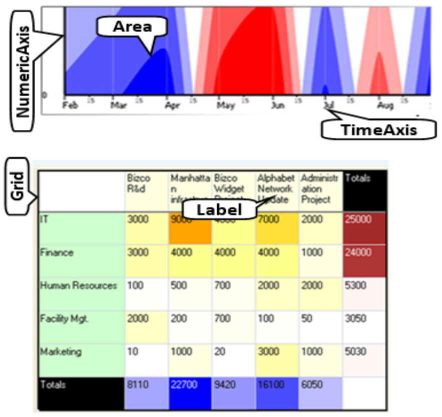
In conclusion, in Protovis it is necessary for a visualization creator to have programming knowledge (e.g. declare a variable, define a for loop). Using basic blocks and dynamic properties made it possible to customize individual basic blocks without the need for loops.

In uVis, we created most of the custom pie chart without real programming. The `DataSource` was filtered using a where clause in SQL style. The properties were dynamically customized by spreadsheet-like formulas that refer to data fields and other properties. Using a basic block (`PieSlice`) allowed the customizability of individual pie slices. To let pie slices respond to click events, the designer needed to write three short assignments. This is a light version of programming, but we believe there is no way around it.

4 CONCLUSIONS AND FUTURE WORK

In this paper we showed that it is possible to create customizable visualizations by combining building blocks linked with uVis formulas. This approach allowed the customization of individual basic blocks in the visualizations. However, the more advanced the visualization, the more challenging the formulas become for the designer.

We believe uVis can create a multitude of advanced visualization, but this needs to be investigated more deeply. We plan to implement more advanced visualizations and look into how our approach can support it. We are currently upgrading uVis from a proof-to-of-concept visualization tool to a more stable tool. This will enable us to evaluate our approach with real designers. Moreover, we plan to investigate to what extent interaction can be made without real programming.



	Bizco R&d	Manhatta n infr	Bizco Widget Project	Alphabet Network Update	Administr ation Project	Totals
IT	3000	9000	[illegible]	7000	2000	25000
Finance	3000	4000	4000	4000	1000	24000
Human Resources	100	500	700	2000	2000	5300
Facility Mgt.	2000	200	700	100	50	3050
Marketing	10	1000	20	3000	1000	5030
Totals	8110	22700	9420	16100	6050	

Figure 3: From top to bottom: Customizable visualizations created with uVis: Horizon Graphs and Heat Map.

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