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RESEARCH REPORT

STOOG: STYLE-SHEETS-BASED TOOLKIT FOR GRAPH VISUALIZATION

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Abstract: The information visualization process can be described as a set of transformations applied to raw data to produce interactive graphical representations of information for end-users. A challenge in information visualization is to provide flexible and powerful ways of describing and controlling this process. Most work in this domain address the problem at either application level or toolkit level. Approaches at the toolkit level are devoted to developers while approaches at the application level are devoted to end-users. Our approach build on previous work but goes one step beyond by proposing a unifying view of this process that can be used by both developers and end-users. Our contribution is a system named STOOG with a three-fold contribution: (1) a style-sheets based language for the explicit description of the transformation process at stake in information visualization, (2) an application that automatically builds interactive and graphical visualization of data based on style-sheet descriptions, (3) a user interface devoted to the conception of style sheets. In this paper, we present STOOG basic concepts and mechanisms and provide a case study to illustrate the benefits of using STOOG for the interactive and visual exploration of information.

1 INTRODUCTION

Over the past years, the visualization process has been described as a set of *transformations* that applies to *data* to produce interactive *graphical representations*. Several models including dataflow model (Card et al. 1999) can be used to describe these transformations. A large amount of systems are based on the data flow model. In (Card et al. 1999, Baudel 2003) information visualization takes as input one or more data tables. In (Heer 2005) raw data is transformed to abstract data composed of entities: nodes or edges.

More precisely, we are interested in data represented by clustered graphs and multivariate graphs. A *multivariate graphs* is a graph where each data element, node or edge, is associated to several attributes. A *simple clustered graph* is a graph where each node is associated to a group named *cluster*. Fig. 1 shows a sample of a simple clustered and multivariate graph.

We define a *dataset* as a set of *data elements*. In our case of simple clustered graphs, data elements are either nodes, edges or clusters. We define a *graphical representation* as the view displayed on the computer screen. We name the *coding function*

the description of transformations that produce graphical representations of non graphic data by, taking as input both *datasets* and *user interactions* and *coding functions*. The rational for these *coding function* has its origins in the seminal work of Bertin (Bertin, 1977) on the semiology of graphics. General purpose toolkits for information visualization such as Prefuse (Heer 2005) make coding function key elements for the developers eager to build interactive visualizations of information. Other approaches for building visualization such as interpreted languages like DOT (Gansner and North 2000) for example handle coding as the basis for building views.

Most approaches comes with different characterizations of these coding functions at stake. By building on previous work, our aim in this paper is to provide a powerful and flexible way for the description of *coding functions* for information visualization of multivariate clustered graphs both at the level of the developer or at the level of the end-user.

Our approach is a to propose a system named STOOG with a three-fold contribution: (1) a style-sheet based language for the explicit description of coding functions, (2) an application that automatically builds interactive and graphical views

from on STOOG style-sheet based on coding descriptions and raw data, (3) a user interface aimed at end-users to support the conception and generation of coding functions.

The mix of the three contributions is important in order to bridge the gap between usually two complementary yet separated approaches: one the one hand the toolkit approach devoted to developers and on the other hand the application approach devoted to end-user. It is important to stress that bridging the gap between these two approaches is important to gain in flexibility and expressivity for the end-user and at the same time save efforts and development time for the developers.

In this regard, our approach compares to the approach of Tableau Software (Hanrahan, 2007) project (<http://www.tableausoftware.com/>). The main differences between their approach and our contribution lies in the fact that we consider multi-level graphs as the basis for representing data and that we propose to make the style-sheet language that describes the coding functions both explicit and open.

Hence, STOOG presents several strengths over existing work. Firstly, the high level language makes semiotic analysis possible thanks to the manipulation of abstract concepts. Secondly, STOOG interprets the description language and builds an interactive visualization of any data set accordingly. Thirdly, the user interface makes dynamic customizations of existing representation possible and easy.

The style-sheet based language of STOOG enables the manipulation of high level concepts such as *graphical representations*, *graphical structures* or *properties* by the user. Four mechanisms are proposed in this language: (1) the matching mechanism which makes possible the association of one or more representations to a set of data elements, (2) the coding mechanism corresponding to the association of data attributes and visual variables, (3) the cascading mechanism implementing the inheritance of properties and structures and (4) the interaction mechanism defining the representation of data during the interaction.

It is important to stress that these mechanisms were meant to be coherent with other approaches where form are explicitly described independently of its content such as in HTML/CSS or XML/XSLT approaches but our approach is STOOG is different and more general because the data handled in STOOG is not limited to HTML/XML documents. Indeed, STOOG handles any raw data set. Another analogy with STOOG style sheets can be found in SVG stylesheets but here again, SVG style sheets are limited to SVG documents. They do not handle

the coding functions for any set of multivariate and clustered data as is the case of STOOG.

STOOG is implemented using Java and supports the generation of views from raw data and coding functions. It further supports the rendering and interaction with these views. Moreover, if useful, extending STOOG style-sheet based language can be performed by a developer to account for more specific types of coding. STOOG is available for download on the web and directly reusable in any Java application.

This paper is divided in five sections. We firstly present related works. Secondly, we define STOOG style sheet language, the concepts and the mechanisms to handle these concepts. Thirdly, we present STOOG through a use case. Fourthly we expose the user interface devoted to the conception and generation of style sheets for end-users. We then conclude and discuss future work.

2 RELATED WORK

Over the past year, several approaches have demonstrated the importance of providing adapted tools for data visualization. We detail previous work on tools for data visualization and situate our contribution in the domain.

2.1 Visualization Tools

Jeffrey Heer has shown in (Heer 2005) the interest of providing toolkits for interactive visualization of information. One of the first toolkit that he proposed called Prefuse, transforms raw data to abstract data and, thanks to actions, further transforms abstract data to visual items. The visual items are finally drawn thanks to renderers. The toolkit is used by a lot of visualization application that build on top of Prefuse for visualizing data in various domains: graph community visualization (Perer et al. 2006), lexical visualization (Collins 2006), cartographic visualization (Phan et al. 05), collaborative visualization (Heer and Viégas 2007) etc.

In (Adar 2006) Guess is another system devoted to graph visualization. Guess highlights the need to have interfaces for customizing rendering by visual attributes. The graph rendering is determined by the user thanks to queries. These queries are written in Gython an extension of the Jython system (a Java interpreter for the Python language). The tool supports generation of charts, computation of convex hulls. Selection of data elements helped on data values criterion or topology criterion.

In GraphViz (Gansner and North 2000) authors present the DOT language that supports the

generation of views. Graphs are first described in a file using DOT language, the file is further interpreted by GraphViz which gives the rendering and layout. The DOT language is used mainly for its simplicity.

The Protovis toolkit (Bostock and Heer 09) builds upon lessons learned from Prefuse and proposes visualization by composing simple graphical marks. Protovis is implemented in JavaScript with rendering in HTML, SVG and Flash. The Protovis toolkit constitutes an excellent way to produce aesthetic charts for websites.

In (Mackinlay et al. 07) ShowMe is described as a set of user interface commands for the automatic generation of presentations. Presentations are further integrated into Tableau Software. Views are specified in an algebraic language: the VizQL language. In (Cammarano et al. 07) the authors propose an automatic technique for the visualization of heterogeneous data. The authors are more precisely interested to match data attributes to visualization attributes. The authors use the RDF format.

In (Pietriga 2006) the GSS language is presented Graph Style Sheet language for semantic web data visualization. The system offers visualization of RDF data as a directed labeled graph. The author introduces the idea of using style sheets for graph visualization.

Cascading style sheets (W3C 2006) are used for the presentation of HTML documents but also used in languages as Flex (Kazoun et al. 2007) or in formats as SVG (Eisenberg 2002).

In (Baudel 2004) the ILOG Discovery tool is proposed. The tool proposes the description of interactive charts using style sheets. The tool is based on model defined in (Baudel 2003). The model is declarative and defines fixed dataflow architecture.

2.2 Our contribution

In this section we situate our contribution amongst the previously detailed contributions. Over the past decades several toolkits such as Prefuse or Guess (Heer 2005, Adar 2006, Bostock et al. 2009) have provided very thoughtful ways of describing *coding functions*. Most toolkit provide flexible and powerful ways of describing coding but their usage is devoted to developers not end-users. Therefore to suit the needs of end-users, applications have to be developed for different application context and users. Even if these new toolkits help a lot, this is still very time consuming for developers and frustrating for end-users. Indeed, our own experiments with end-users shows that the key object of interest for many end-users is the coding

functions. However, lots of visualization applications provide less control over these functions to the end-users than what is possible at the toolkit level.

Therefore our contribution is to build on previous work to provide both end-users and developers with ways of understanding and expressing coding functions.

STOOG can be used to generate views pluggable in other applications or web sites. The view is initialized by two parameters: graph data and a style sheet. The aim of the style sheet is to describe the coding functions.

Style-sheet concepts are easy to understand and use for both end-users and programmers. STOOG style sheets can be created and changed on the fly by end-users. STOOG can either be used as a STOOG standalone application by end-users or be integrated in other applications by developers. The style-sheet language definition of STOOG can also be extended by developers.

Contrary to toolkits where coding is implemented in the code, like in Prefuse (Heer 2005), the style-sheet approach makes it possible to handle different encoding without recompiling applications. We also propose a representation based on the composition of graphical representations or shapes. In the system proposed in (Adar 2006), the only shape can be associated to each data element.

In (Bostock et al. 2009, Baudel 2003) the systems proposed are dedicated to data visualization and more precisely to charts.

Contrary to (Eisenberg, 2002), we propose dynamic links between data attribute and visual variables. We also use a mechanism selecting a subset of data elements and associating a graphical representation.

The approach by Pietriga on graph style sheets (GSS) (Pietriga 2006) can be considered as very similar to our approach. However, there are several differences that justifies in our contribution. We firstly propose to account for interaction in coding function rather than static coding. Secondly, we are not limited to a set of predefined shapes, STOOG supports the composition of shapes. Thirdly, the data managed in (Pietriga 2006) are RDF databases which can be represented by a simple labeled graph. We also consider more general models of clustered graph and multivariate graphs. Fourthly, our proposed toolkit is pluggable in a web browser or an existing application. Lastly, we have implemented the cascading mechanism proposed in CSS for our style sheets. Moreover, we have improved the mechanism by adding cascading of graphical representations.

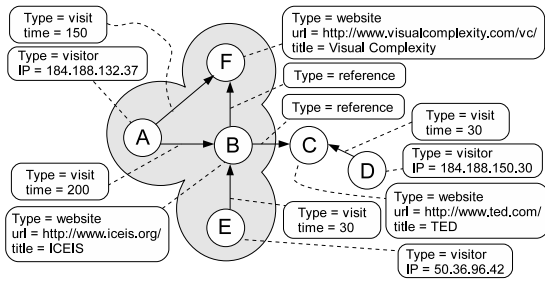


Figure 1: A simple sample of multivariate graph

3 STYLE SHEET LANGUAGE

In (Bertin 1977), Bertin outlines six visual variables: shape, size, value, grain, color and orientation. Similarly, our style sheet language makes the definition of visual variable possible thanks to concepts such as *graphical representations*, *graphical structures* and *attributes*. In this section, we outline the four core mechanisms that we found useful for STOOG style-sheets: matching, coding, cascading and interaction. These mechanisms enables the association between data and visual variables.

3.1 Basic Principles

A style sheet describes *graphical representations*. Each representation is associated to a class of data elements. In the precise case of graphs, data elements are *Nodes*, *Edges* or *Clusters*.

An important difference between our approach and other approaches like (Adar 2006) is the possibility of composing data element representations with *graphical structures*. *Graphical structures* are defined by attributes. Each attribute is associated to a list of values.

In order to illustrate our discussion, we present a style sheet sample (Fig. 2) applied on the graph (Fig. 1) and the associated generated visualization (Fig. 3). The Fig. 1 presents visits of websites by internet users. We decide to represent internet users and websites by labeled nodes visits and references by labeled edges. Fig. 3 presents the result after the application of the style sheet. Internet users are represented by a schematic person. Internet websites are represented by thumbs. Visits are represented by links in blue, the thickness is proportional with the time spent by a given user on a given website. References are represented by links in green. Internet users in pink have an IP address beginning by '184.188'.

GRAPHICAL REPRESENTATIONS

```

Website -> Node {
  URL{ shadow : 'yes';
        mirror : 'yes';
        width_percent : 100;
        height_percent : 100;
        position : 100,110;
        anchor_name : 'Main';
        name : 'web_icon';
        url : ''+@self.url; }
}
Website_hover -> Node {
  TextBox{ text : @self.title;
           position : 50,85;
           box_size : 200,25;
           box_visible : 'no';
           style : 'BOLD';
           point: '20 pt'; }
}
Visitor -> Node {
  TextBox { text : 'IP : ''+@self.IP;
           position : 50,60;
           box_size : 200,25;
           box_visible : 'no';
           style : 'BOLD';
           point: '20 pt';
           name : 'IPText'; }
}
Polygon{ points : 135,...,160,120;
         fill_color : 0,0,0,100;
         draw_color : 0,0,0,100;
         anchor_name : 'Main';
         bezier : 'yes';
         name : 'Body';
         mirror : 'yes'; }
Oval { position : 130,83;
       size : 30,30;
       fill_color : 0,0,0,100;
       draw_color : 0,0,0,100;
       name : 'Head'; }
Visitor_sel -> Node {
  Polygon{ fill_color : 255,0,0,100;
          draw_color : 255,0,0,100;
          name : 'Body'; }
  TextBox { name : 'IPText';
          fill_color : 255,0,0,100; }
  Oval { fill_color : 255,0,0,100;
        draw_color : 255,0,0,100;
        name : 'Head'; }
}
Cluster -> Node {
  Region { fill_color : 100,200,255,50;
          draw_color : 0,0,255;
          name : 'cluster'; }
}
Lien -> Edge {
  Line { start_anchor : 'Main';
        end_anchor : 'Main';
        thickness : @self.time/15;
        name : 'lien';
        fill_color : 100,200,255,100; }
}
Ref -> Edge {
  Line { start_anchor : 'Main';
        end_anchor : 'Main';
        thickness : 5;
        name : 'lien';
        fill_color : 0,255,0,100; }
}
ASSOCIATIONS
NODE
(@self.type='website')-> Website;
(NOT @f_bool.is_leaf(@self)) -> Cluster;
(@self.type='visitor')-> Visitor;
(@self.type='visitor' AND
@f_bool.start_with(@self.IP,'184.188'))
->Visitor_sel;
EDGE
(@self.type='visit') -> Lien;
(@self.type='reference')-> Ref;
INTERACTIONS
NODE
{ON_HOVER
(@self.type='website') -> Website;
(@self.type='website') -> Website_hover;
}

```

Figure 2: A sample of style sheet

The style sheet is composed of a list of graphical representations. Each graphical representation is composed of graphical structures themselves composed of attributes. Graphical representations are noted on Fig. 2 from R1 to R7. The representation R3 named *visitor* is composed of three graphical structures: a *text box*, a *polygon*, an *oval*. The *text box* helps for displaying the IP address. The *polygon* depicts the visitor body. The *oval* depicts the visitor head.

In this style sheet language, edges can be linked to any structure. When the creation of an edge representation is done we must specify the name of the source port and the name of the target port for binding the edge representation. The name is given by the *anchor-name* property.

This section has shown how to define graphical representations. We are now interested in the four proposed mechanisms: coding mechanism, matching mechanism, cascading mechanism and interaction mechanism.

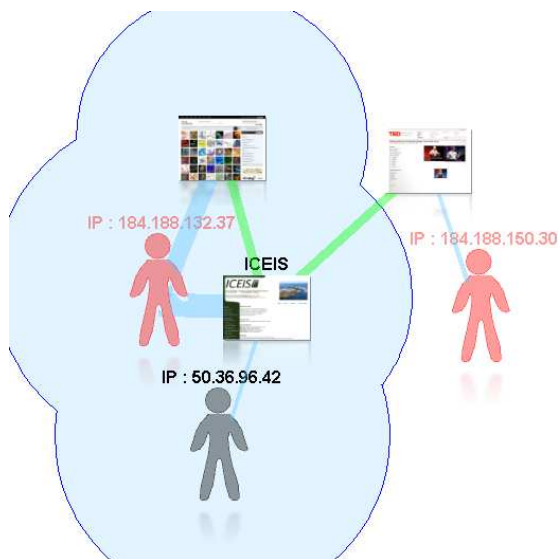


Figure 3: A simple sample of transformed graph using a style sheet.

3.2 Coding Mechanism

The coding mechanism consists in defining how data attributes are represented by visual attributes. Each visual attribute value is described by an expression. An expression can be:

- a constant,
- a data attribute or
- a binary operation with two operands themselves expressions,
- an arithmetic function parameterized by expressions.

Fig. 4 shows the grammar for arithmetic expression, an example of accepted expression and the associated abstract syntax tree.

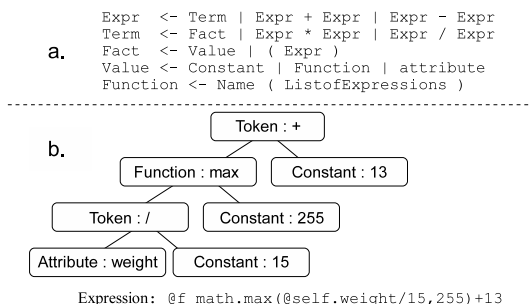


Figure 4: Simplified grammar for arithmetic expressions

3.3 Matching Mechanism

The matching mechanism consists in associating a set of data elements (i.e. nodes, edges or clusters) to a set of representations. The associated elements are selected thanks to Boolean expressions. If a Boolean expression is satisfied, we associate a given representation to a set of selected data elements.

A Boolean expression can be

- a constant (True or False),
- an operator (Not, And, Or) with for each operand a Boolean expression,
- a comparison (<=, <, >, >=, <>) composed of two compared expressions cf. Fig 4,
- an operator testing the existence of an attribute given as a parameter.

The Fig. 5 presents the followed grammar for Boolean expression, an example of accepted Boolean expression and the associated abstract syntax tree.

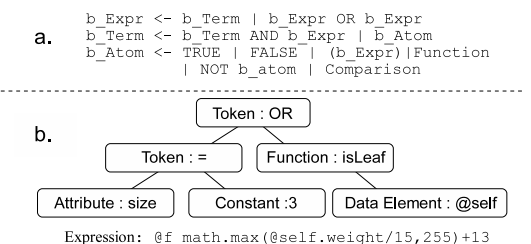


Figure 5: Simplified grammar of Boolean expressions

3.4 Cascading Mechanism

Cascaded representations are processed when a data element is associated to several representations. The cascading algorithm takes an ordered set of

representations in parameter and produces a final representation.

The cascading of two representations A and B is done by producing a new representation C. The representation C is made of all structures in A and B. As with other CSS-like languages, a problem might arise from incompatible definitions occurring in the distinct representation of A and B. It is solved similarly: two structures are considered equal if the two structures have the same name. When two structures are equal in the representation of A and B the result in C is a structure of the same name. However, the definition differs and accounts for both A and B definitions. If ever these definitions are contradictory, then the latest definition is kept in C.

The cascading of a set of N representations is done by a successive cascade of one representation after another. Fig. 6 depicts the cascading done during the rendering of the view (Fig. 3).













	B	C	F
Website			
Website_hover	ICEIS		
Final Cascaded representation			
	D	E	A
Visitor	IP : 184.188.150.30 	IP : 50.36.96.42 	IP : 184.188.132.37 
Visitor_sel	Color Redefined		Color Redefined
Final Cascaded representation			

Figure 6: A sample illustrate cascading mechanism

3.5 Interaction Mechanism

The interaction mechanism corresponds to the modification of the representation during the interaction. For each possible interaction we select data elements thanks to Boolean expressions. We affect to these previously selected data elements a new representation.

Some interactions are not fully compatible the cascading mechanism as explained in the previous section. We use the notion of *dynamic cascading*. Dynamic cascading does not replace the previous representation by a new representation but cascade

it. In the precise case of interaction as the *selection* interaction we want sometimes to add a colored filter in order to mean that the data element is selected. The dynamic cascading makes this modification possible without knowing in advance the previous representation. This kind of cascading is implemented only for the selection of elements. Dynamic cascading proved to be very useful and might extend to other situations. Therefore, we plan to support it in a more general way in future versions of the system. We would then add a keyword in future version in order to explicit the type of cascading desired.

4 GRAPH VIEWER

In this section, we present the viewer which is the part of STOOG responsible for rendering. The viewer is implemented in Java. Hence the viewer can be pluggable in any web browser supporting applets. This section is divided in three parts. Firstly, we present the properties of the viewer. Secondly, we expose the simplest interactions. Lastly, through a use case, we present advanced interactions.

4.1 Properties

The viewer is decomposable in three parts: the parser transforming style sheets on a syntax tree, the interpreter transforming this syntax tree on the structured model, the renderer displaying elements on the screen.

The parsing process is implemented using the *SableCC* tool. It is a compiler compiler taking in parameter a grammar and generating the Java parser for this grammar. This parser is used to create the abstract syntax trees of ours style sheets.

The interpreter takes the graph structure underlying the data to display as a parameter and the abstract syntax tree issued from the graph style sheet. It transforms the abstract syntax tree in a *graphical representation model* and associates each data element to a *graphical representation*. **The renderer** generates the interactive visualization on the screen in relation with the model. It is in charge of: drawing the graph, modifying the representations during the user interaction, and displaying animations such as layout algorithms or zoom.

The most important aspects of our style sheet graph viewer are its extensible capacities. The tool supports dynamic management of structures. Structures are imported dynamically using the Java introspection. Each structure must determine the attributes available and its own rendering. The

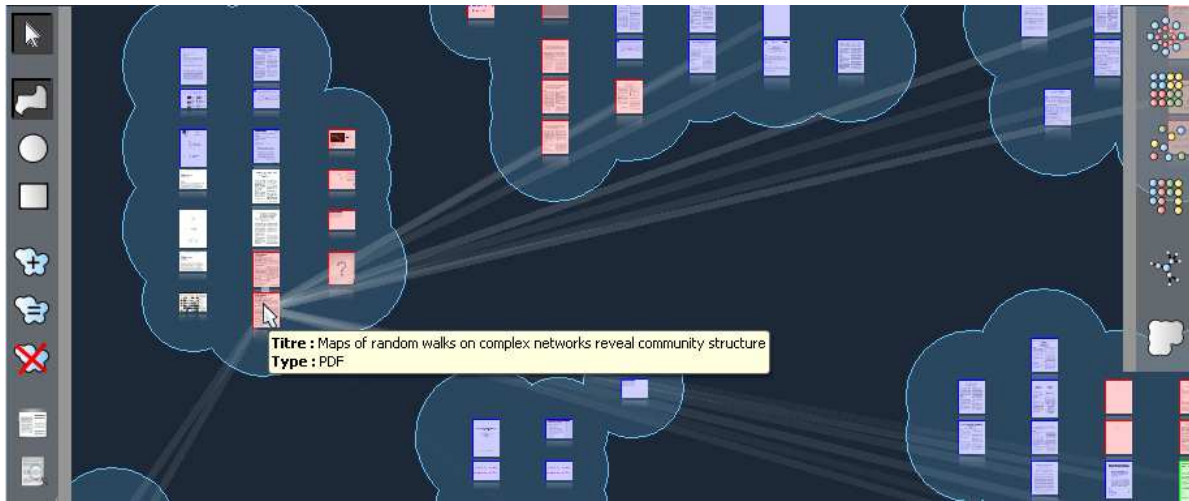


Figure 7: A sample of visualization using STOOG

arithmetic and Boolean functions, available in expression, are dynamic and improvable by specifying the classes containing the functions. A developer can therefore determine new kinds of structures. For instance, we can imagine structures using internet such as the structure *URL* (Fig. 2) which creates a thumb of web site.

4.2 Simple Usage

A simple way to use our viewer is in the applet functionality. Indeed, the toolkit is pluggable in a web browser as an applet parameterized by two parameters: the graph to display, the graph style-sheet to use. Other optional parameters are available as the layout. During the execution both style sheets and graph can be changed on-the-fly using drag and drop.

4.3 Advanced Usages

We present in this part the use of STOOG through a project. This project aims to study user classification of documents. Each user creates this own database of web documents. The documents are in relationship thanks to a similarity function parameterized by two documents and given a score between 0 and 1. The score is near to zero if the two documents are far semantically. The score is close to one if the two documents are similar. We are interested to visualize and clusters these documents. The obtained result is visible in the Fig. 7. The STOOG tool is integrated as a Java component. The documents are represented by thumbs. Clusters are represented by bubbles shapes around documents. Links between documents are visible on mouse over. Documents drawn in blue, red and green are in three

different sets of selection. Menus have been added on the left side and on the right side to offer functionalities for selections, layout, manual clustering and automated clustering.

The clusters can be created either manually or automatically. Clusters are created manually using the STOOG selection or automatically using the Java implementation of the MCL algorithm (Stijn van Dongen 2000). Some interactions are not implementable using the graph style sheet such as the display of incident edges on mouse hover. For this kind of interaction it is possible to define the representation using the graph style sheet with a name of interaction not predefined. The developer must then simply specify the name of the modification of representation and of the data element to modify during the interaction.

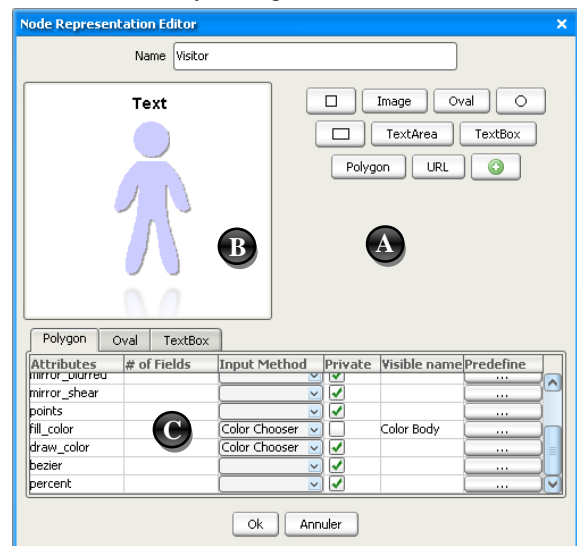


Figure 8: Node Representation Editor

5. STYLE SHEET EDITOR

Our style sheet editor is divided in two parts: a creator and a graph style sheet editor. The creator makes the creation of representations on-the-shelf possible. The graph style sheet editor gives a list of representations possible and enables the association between data and visual attributes.

5.1 Representation on-the-shelf

The creator (Fig. 8) proposes the construction of representations on-the-shelf. It is divided in three sections: (A) the list of structures, (B) the draw panel, (C) the list of attributes.

The list of structures is defined using the import button. The import button triggers input dialog asking for a structure class name. The structure is imported thanks to the Java introspection mechanism. The list of structures is stored in a for further uses.

The draw panel makes the positioning of structures possible. It offers a preview of the representation.

The list of attributes shows all available attributes for each structure placed on the draw panel. For each attribute the user can specify predefined values, the visibility of the attribute (private or not), the visible name and the input method. For instance the attribute *fill_color* of the instance of polygon is public (i.e. it will appear in the graph style sheet editor), the visible name is

'*Color Body*'. The color is typed using a color chooser. When the button "ok" is pressed the representation is available on-the-shelf.

5.2 Graph style sheet editor

The graph style sheet editor Fig. 9 is divided in four parts: (A) data, (B) representations, (C) rules and (D) rendering.

The data section makes the specification of a dataset possible. The data is considered as an instance nevertheless enables functionalities as auto-completion of data attributes.

The representation section exposes a set of available representations for graph style sheets. One click triggers the association of the representation to the selected rule and the adding of a tab in the rendering section.

The rule section exposes a set of rules created by the user. The rule is defined by a name, a condition of application named expression, an application mode and a kind of data element.

The rendering section presents the visual variables associated to the representation.

In the example in Fig. 9 the user has created a rule named "visitor". The rule is applied on the *visitor node*. The rendering associated to the rule is a *visitor representation* created (Fig. 8). The generated form concatenates the fields of all structures in the graphical representation. Only public attributes are visible, with the input method and the name chosen during the conception.

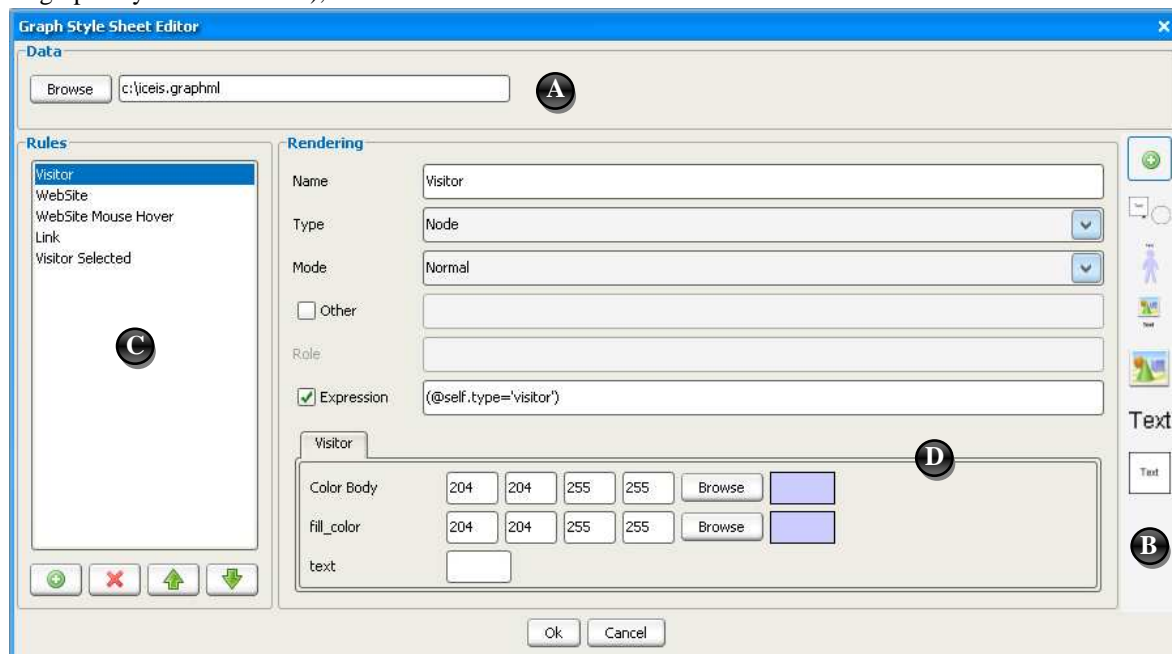


Figure 9: Graph Style Sheet Editor

6. CONCLUSION

In this paper we have proposed a toolkit for graph visualization, more precisely for the visualization of multivariate graphs and clustered graphs. Our approach is based on style sheets. We have introduced a new language for the definition of style sheets which proposes new concepts and four mechanisms in order to handle these concepts: the matching, the coding, the cascading, and the interaction. By providing and integrating (1) an extensible language for style-sheet definition, (2) both a standalone application and an API supporting the rendering and interaction of visualization resulting from encoding raw data according to STOOG Style sheets and (3) a user interface to facilitate the creation and reuse of style-sheets. We believe that by using STOOG, both end-users and developers will save time and efforts in their attempts to visually explore large amounts of information.

7. PERSPECTIVE

In the future we plan to extend our language with more complex interactions. We are interested in extending our toolkit for graph hierarchies. Finally we plan to conduct controlled experiments on different users.

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