Modeling Users for Adaptive Semantics Visualizations

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Abstract. The automatic adaptation of information visualization systems to the requirements of users plays a key-role in today's research. Different approaches from both disciplines try to face this phenomenon. The modeling of user is an essential part of a user-centered adaptation of visualization. In this paper we introduce a new approach for modeling users especially for semantic visualization systems. The approach consists of a three dimensional model, where semantic data, user and visualization are set in relation in different abstraction layer.

Keywords: Adaptive Visualization, Semantic Visualization, User Model.

1 Introduction

The conflation of the research areas Information Visualization and Adaptive Systems plays more and more a key-role in today's research. Both research fields declare the adaptation of information visualization systems as a main challenge. Information Visualization recognizes the development of "novel interaction algorithms incorporating machine recognition of the actual user intent and appropriate adaptation of main display parameters such as the level of detail by which the data is presented" [17] as a main challenge. The research in Adaptive Systems already presented first attempts to adapt visualizations to the different characteristics of users. Main challenges for the adaptation of the visualization to the user are the identification of relevant users' attributes, their processing from users' interaction with graphical systems and the adaptation of the visualization based on the gathered information. This important information is designed and persisted in user models, which mostly provide a domain-specific model of certain users attributes. The information is gathered implicit from the interaction of the user with a set of data, which is currently modeled as a common text-based user interface.

With the adaptation of visualizations another research challenge appears in this area: the modeling of users attributes, based on their interaction with a pure graphical representation and the application of the gathered information to adapt a pure graphical representation and visualization respectively.

In the following paper we present a new approach for domain-independent user modeling for the adaptation of graphical information systems especially for semantic visualization.

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The approach introduces a three-dimensional matrix consisting of both user attributes that are relevant for visualization and visualization parameters that are important for the perception of information with visualizations. The identified parameters of visualizations are classified into two levels of abstraction: First the visualization-type adaptation, which represents a set of easy-to-use and established visualization methods and layouts and second the parameterization of each selected and recommended visualization, e.g. color and size of entities, level of zoom or level of details. The attributes of the visualizations evinces a static character and fill out two dimensions of our approach, on the one hand the several identified visualization types and on the other hand the parameterization of each visualization type.

In contrary to the visualization dimension the user dimension evinces a dynamic character based on the users' behavior. Here the most relevant information about users' interaction with the graphical representation of information is mapped to the two dimensions of the visualizations. In this dimension not only the interaction with the data behind the graphical representation is registered, but also the interaction with several visualizations. Therefore the user gets a new approach of multiple-visualization, a "Visualization Cockpit" and the interaction with each of the visualizations is measured for example to model a relation between user and the visualization-type dimension.

In the first section of this paper we give a general overview about main aspects of user modeling, followed by existing adaptive visualization systems. the existing visualization adaption systems and their user-modeling method. The following section will introduce the new approach of the three-dimensional user modeling. After that the most relevant attributes of both, the visualizations and their parameterizations and the user will be described.

2 User Models and Adaptive Systems

A user-centered adaptation of any system needs information and knowledge about the user. Based on these users' information a system is able to provide a user-centered adaptation effect. The mentioned information about users is commonly described as knowledge about the user in user models. The following chapter will give an overview about the way how this information is modeled and how user models can be classified.

To envision an appropriate picture of user models the classification of Slemann [28] will be used, which categorizes user models in the following layers:

- *Nature: What is being modeled?*
- *Structure: How this information is represented*
- *User modeling approaches: How different kinds of models are maintained*

Thus our approach focuses on the nature of a user models we will give an overview of approaches on the nature of user models provide state-of-the-art examples for the approaches. For the investigation of user models for information or semantic visualization it is further necessary to differentiate between those systems, which uses information retrieval techniques for filtering, ordering and organizing information and those, which uses and models users knowledge and are often used in Intelligent Tutoring System (ITS) [21] and knowledge systems.

The information retrieval systems are often used in recommendation systems, where the user interests are modeled over time using data mining approaches ([26], [27]). Besides these approaches which focus on user interest the most popular user features, which models users as individuals are: *knowledge*, *interests*, *goals*, *background* and *individual traits*. . [8] In the following we describe these often used features for modeling users:

Knowledge: User's knowledge is the most important feature, especially for e-Learning system, e.g. Adaptive Hypermedia Systems (AHS) and Adaptive Educactional Systems. [8] This feature is used in the majority of systems by both, for navigation through a knowledge domain and an adaptive presentation. [8]. The simplest and most common way to model the user's knowledge is the *scalar model*, which estimates the user's level of knowledge. A scalar model may consist of quantitative or qualitative values. Quantitative values may be a number ranging, in which the user is classified. The qualitative scalar model classifies a user into several levels of knowledge within a knowledge domain, e. g. Novice to Expert. The scalar model is very similar to stereo type systems, where different users' are compared with each other. Different examples ([21], [9], [5], [6], [7]) of scalar model-based adaptive systems shows, that despite the scalar modeling is a very simple way to model user, the systems provide promising und useful adaptation effects.

Another approach for modeling users' knowledge is the structural model, "which *assumes that the body of domain knowledge can be divided into certain independent fragments*." ([8], p. 7) The most popular form of structural model is the overlay model [8], which represents an individual user's knowledge by a subset of a given domain level. The simplest way of an overlay model assigns a Boolean value to each knowledge fragment compared to the domain knowledge. This value can be enhanced by the introduced scalar model, where each fragment gets a qualitative or quantitative value. The second model, a combination of the scalar model and the simple overlay model has been established in different systems ([15], [25]).

Other approaches for designing and modeling users' knowledge are *bug model,* which compares the non-knowledge of the user ([18], [31]) and the genetic model [11].

User Interest: User interest is the most important part for of a user profile in adaptive information retrieval and filtering systems, e.g. recommendation systems, that deals with large amount of information and adapts (filtering, highlighting) the relevant part of the large for the user.

There exists two different way, how user interest can be modeled: The weighed vector of keywords method [2], a keyword-level approach, which is still the most popular model for model user interest. And the weighed overlay model, where user interest are modeled as a weighed overlay of a concept-level. This model is very similar to the described knowledge overlay model. User interests are represented as an overlay of a concept-level model of the domain that the system covers. Because the two models, knowledge overlay model and concept-level weighed overlay model are very similar, many systems modeling users by using these both models by separating the overlay over the same network of concepts ([3], [24]).

Goals and Tasks: The user goals and tasks represent the immediate purpose of a user within a system. [8] This can be the need for certain information, solving a given problem, learning a specific learning object or fulfilling a certain task. The information about users' tasks and goals (or intentions) can be used by adaptive help systems ([12], [10]) to provide an adequate help in during several steps of solving a problem while working with a system. Further Intelligent Tutoring Systems [21], especially with the focus for conveying procedural and problem-solving knowledge; analyze goals and tasks of the users.

Background and Individual Traits: Background and Individual Traits are common and aggregate names for several user features outside the core domain and define the user as an individual. For gathering knowledge about these two features more than only user interviews are needed. The modeling needs specially-designed psychological tests. [8] The most famous system, which build a user profile from the cognitive abilities, is CUMAPH [29].

3 Adaptive Visualizations

For the community of Information Visualization, the way from data-oriented visualization to a more human-centered information presentation plays a key-role. In 2007, one of the ten main challenges for Visual Analytics and Information Visualization respectively was the inclusion of the semantics or context (data characteristics, user goals, etc.) in information visualization systems [30]. In the following year, especially the human as an implication and decision factor for information visualization was placed in the forefront of the research. Keim et al. declared the aspect of User Acceptability as one of the most important technical factors for deploying Information Visualization for the changing requirements of users. [1718] The strengthening of the ongoing trend to involve the user with her individual intentions and preferences in the forming process of Information Visualization is noticeable in the challenges and scopes of Visual Analytics in 2008, where the adaptation of information visualization systems was proclaimed. Thus, one of the most important challenges is the development of "novel interaction algorithms incorporating machine recognition of the actual user intent and appropriate adaptation of main display parameters such as the level of detail, data selection, etc. by which the data is presented" ([17], p. 162).

Already different approaches have been proposed to support an automatic or semi-automatic adaptation of UIs. Cicero, for example is a component-oriented architecture [4], where a central UI adaptation manager is used; on the contrary agent-based environments [14], where UI models are transformed and rendered into different platforms adapts user interfaces to different impact factors. The only applications that adapt the visualization to certain impact factors, e.g. user interactions or user-goals are the following applications:

Gotz and Wen are using the user interactions for analyzing and extracting a certain "behavioral-pattern", which is used to suggest a different visual representation of the data [13]. The impact factors for their visualization-recommendation are the iterative interactions of users, which is used to recognize a user-behavior. Based on the recognized behavior a certain visualization type (Line Graph, Fan Lens, Parallel Coordinates or Bar Charts) is recommended for the user. But a visualization type has always characteristics and parameters, e.g. color of entities, order, size, layout etc., which can and should be used for communicating designated information adaptively. On the contrary Ahn & Brusilovsky are adapting visual parameters of a single visualization type and visualize the user-specific relevance of a query [1]. In this case a single static visualization type (Spatial Visualization) is used to represent the searched information.

The related work could point out that the number of existing adaptive visualizations is very limited and these approaches focus either on the adaptation of the visualization type, using a single set of parameters (e.g. [13]) or on the adaptation of the parameters of a given single visualization type [1]. Despite a good research in both areas, a sophisticating system with an adequate user modeling approach especially for the visual representation of the system could not be found.

4 Adaptive Semantics Visualization and User Modeling

In the previous section we could point out that several methods for modeling users in different forms of adaptive application are already developed. We could further point out that the number of adaptive visualizations is very limited, but there is a need and a visible change to a more human-centered view in the development of information visualization systems.

We introduce in this chapter a conceptual design for modeling users especially for the adaptation of visualizations. First we discuss the nature of user information needed for adapting visualizations. Therefore the aspect of information visualization will be investigated as a general way of presenting information. After that the visualization will be considered in several layers of abstraction and a new approach for adapting visualization will be presented.

4.1 Relevant User Features for information Visualization

Information Visualization bridges the gap between complex and huge information and the user. It is one of the most powerful bridges between human and complex information structure: *A picture is worth a thousand words*.

But each picture and with it each way of visualization can be perceived by the individual user in deviate ways. While a textual presentation of information gives little room for interpretation, the visualization of the information can be interpreted in several ways.

It is obvious that visualization and perception are very near to each other. Users' history in interacting and using information visualization systems is very important for modeling her in the context of visualization. With history her experiences with different real and virtual visual artifacts are meant in this context. Users' experience can be modeled as shown in chapter two, as her knowledge. So the users' knowledge or pre-knowledge plays an essential role for choosing the right visualization. But the main question is: "how is a system able to gather information of a user about her experience and pre-knowledge in interacting with visualizations?"

A very easy and obvious way is, to present different visualizations and observe the users' behavior. For the presentation of different visualizations, different metaphors can be used:

- Presenting a single preselected visualization with a set of possible other visualization techniques. *(1)*
- Presenting a (preselected) set of visualization as a multi-view User Interface *(2)*

For the process of pre-selection methods from Visual Analytics ([16], [17]) can be used, which recommends visualizations based on the data, which are visualized.

The following figure demonstrates the described ways of visualization presentation.

Fig. 1. Choosing Visualization for the User Model

From the users' interaction in both presentation ways, the preferred visualization and thus knowledge about the user can be gathered. But of the presentation forms have advantages and disadvantages: The multi-view presentation way treats all of the visualization in the same way and does not manipulate the user. But putting several visualization in one User Interface, may overcharge the user. The single-way visualization is very simple and provides is more easy-to-use visualization way. But this way of presentation may manipulate the user to use the presented visualization. To avoid a manipulation and overcharging of the user and gathering information about the user, a mixture of both presentation forms is a solution: On the hand the user knows explicitly that there exist several visualization types for choosing and on the other hand the multi-view UI is constrained to two visualizations and thus does not overstrains the user.

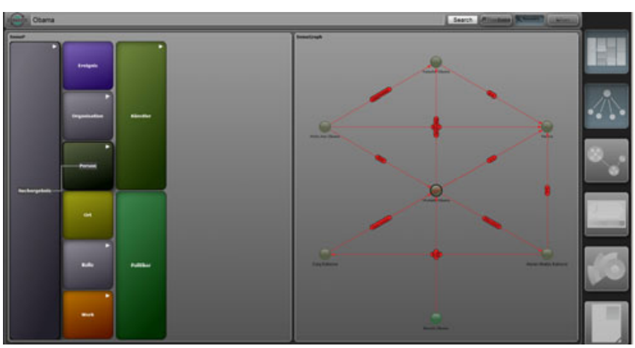

Fig. 2. Mixture of visualization presentation

Information visualization systems visualize huge amounts of data and information respectively, thus the consideration of users' interest is another factor, which brings an added value. Ahn and Brusilovsky already presented in [1] an approach for ordering the items of a search results based on a recommendation system (thus based on user interests). To enhance this method the interaction of the users with the graphical representation of the data are considered too. With the algorithm presented in ([22], [23]) we are analyzing the interactions of users to create a profile of the user interests. The results are highlighted by using different graphical primitives ([22], [23]).

The following figure shows the described mixture.

4.2 Layers of Visualizations of Semantic Data

In the previous section we could point out that there are two natures of user information used and necessary to provide a visualization adaptation. Further we pointed out that different visualization layers are investigated in the process of adaptation and user modeling. In this chapter these layers will be presented, which consists of three so called components. The here described components are developed for visualizing semantics data [20].

General visualized components (GVCs) are abstracted visualizations and form the UI. GVCs are primarily responsible for the selection, placement and initialization of visualization types in their layout layer. In our case, we used a mixture of visualization presentation and the opportunity to choose a visualization type. Choosing a visualization type implicates a kind of preference in the way of the user interaction and perception and models her knowledge.

Semantics visualization components (SVCs) visualize the structure of the semantics data and provide the possibility to interact. SVCs are the real visualization components and consist of one or more visualization algorithms, e.g. force directed or concentric radial. The visualizations are already chosen by the user. Here the user interacts with items (graphical representation of the information) within the visualization. With this information the users' interest are registered and analyzed.

Content Visualization Components (CVCs) are responsible for the presentation of the content referenced by the semantics. Examples for CVCs are pictures or HTML-viewers. They are interactively coupled to one or more SVCs and inherit the semantics, presentation and layout form theses coupled SVCs. If a user chooses the content and navigates through the content, it may implicate a "hit". This part is under investigation.

4.3 Three Dimensions of User Model

We could point out that the interactions with different layers of visualizations give us different information about the user. Interacting with a graphical object, which represents an information entity could be used to change the parameterization of the visualization and gives us information about his interests.

Choosing one or more visualization gives us information about the user's preferences and experiences respectively in interacting with visualization and thus implicates a kind of users' knowledge. We brought three dimensions together: The users with the features interests and knowledge, the data (behind the graphical representation or in a content viewer) used for computing the interests and the visualization with the separation of visualization type (graphical metaphor) and the parameterization of the visualization.

The following figure shows the mentioned three dimensions:

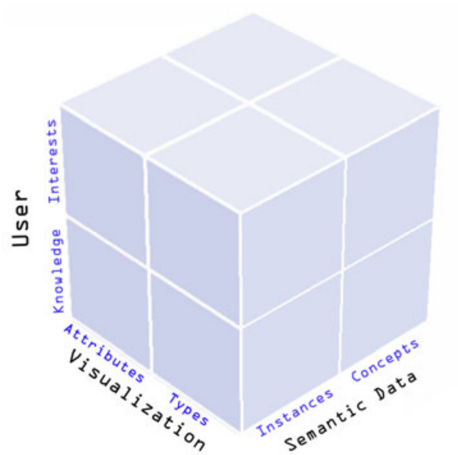

Fig. 3. Three Dimensional User Model

5 Conclusion

In this paper we presented an approach for modeling users especially for semantics visualization. With the usage of interaction analysis systems information about users are analyzed in different levels. The chose of a visualization metaphor is interpreted as information about users' knowledge; further the interaction with a graphical entity and thus the interaction with data is investigated similar to recommendation systems. The parameterization (attributes) of the visualization is adapted based on the interaction with the data, while the recommendation for a visualization type is related to the data (structure, hierarchy) and the interaction of the user within visualization or the chose of visualization.

The further progress of this work includes a comprehensive evaluation that further examines the potentials and benefits of adaptive visualizations. In particular the future work includes a comparison with common presentations with respect to the discovery and analysis more user features and the effects for the user.

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