Meta-model of Information Visualization Based on Treemap

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Abstract. The interpretation and understanding of large quantities of data is a challenge for current information visualization methods. The visualization of information is important as it makes the appropriate acquisition of the information through the visualization possible. The choice of the most appropriate information visualization method before commencing with the resolution of a given visual problem is primordial to obtaining an efficient solution. This article has as its objective to describe an information visualization classification approach based on Treemap, which is able to identify the best information visualization model for a given problem. This is understood through the construction of an adequate information visualization meta-model. Firstly, the actual state of the visualization field is described, and then the rules and criteria used in our research are shown, with the aim of presenting a meta-model proposal based on treemap visualization methods. Besides this, the authors present a case study with the information contained in the periodic table visualization meta-model along with an analysis of the information search time complexity in each of the two meta-models. Finally, an evaluation of the results is presented through the experiments conducted with users and a comparative analysis of the methods based on Treemap and the Periodic Table.

Keywords: Information visualization, information visualization methods, visualization systems, knowledge visualization, selection framework, data visualization, applications, visualization types, visualization problem solving, treemap.

1 Introduction

Currently, the quantity of data available on information systems is incremented in a considerable and continual form, with an elevated quantity of data elements, where each element can contain a wide variety of attributes. This occurs throughout many knowledge domains, thus rendering the applications applied through traditional methods for the visualization and analysis of data, insufficient, complex and inefficient [5].

The Information Visualization (IV) area is a discipline that possesses a new growing field of research, which makes use of a means whereby a given set of information is represented in a form, which allows the user to use it.

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A visualization method is a systematic process based on rules with an external representation both permanent and graphical, which portrays the information in a way that is conducive to the acquisition of knowledge, the development of an elaborated understanding, or the communication of experiences [1].

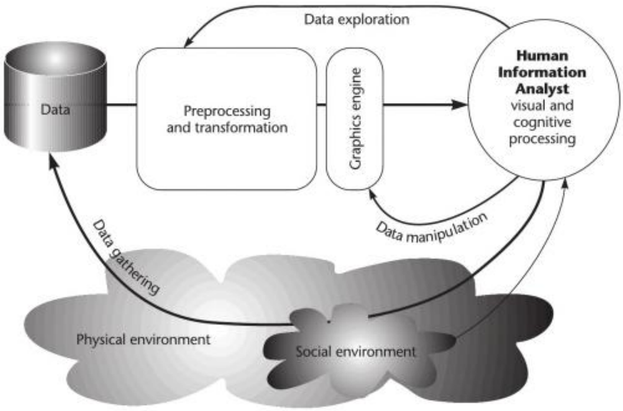

Fig. 1. A Schematic Diagram of the Visualization Process [2]

The visualization provides the user with the ability to understand a large quantity of information as well as resolve problems associated with data. This also allows a user to better perceive standards, such as local features [2].

The visualization process contains four basic stages, illustrated in Fig 1[2]:

- The collection and storing of data;
- The pre-processing stage for transforming data into a form of information that can be understood;
- The visualization of information through the use of graphical algorithms that produce on screen images;
- The cognitive human perception system;

The human brain, in particular its perception and cognition is one of the most interesting models for the development of intelligent systems [4].

An IV process should search for the best information representation to enable the interpretation and understanding of large quantities of data. It has as its principal objective to search for the best form to map the information and limit the quantity of information that will be presented to ensure the best visual perception and cognition of the information by the users. The best way to map is related directly to the desired objective through the representation of the information, be it the facility of the information search, by the emphasis on determined information in relevance to other information, or the organization of the information. This information representation is carried out through the use of visualization criteria and techniques.

The criteria for information visualization make it possible to categorize, identify and search for visualization methods.

The categorization and identification of the visualization methods should facilitate a rapid search structure, which is interactive and easy to use.

Just as there are models for information visualization, there also exist models for the categorization of the IV methods, or be it, models for the information visualization of the information visualization. The latter being denominated as information visualization meta-models.

There exist some meta-model attempts for information visualization, as for example the information visualization for the Periodic Table [1]. However, at the present moment there exists a lack of meta-model that possesses a rapid search structure, which is interactive and of easy manipulation for the search for the most adequate method for solving IV problems.

In this sense this article proposes a generic framework for information visualization based on treemap logic, inspired upon the Periodic Table model proposed. This framework can be seen as a meta-model that permits a visualization representation, able to interpret and comprehend the information and possesses an information search structure which is rapid as well as simple.

2 Criteria for the Classification of Information Visualization

The diverse information visualization models are recognized one from the other through the use of different forms or standards for the graphical representation of the information, denominated in this article as criteria, for the graphical classification and organization of information. These criteria used in the information taxonomy are also used in the classification of the models in the information visualization meta-models.

2.1 Periodic Table Information Visualization

The constituted meta-model presented in [1] classifies the visualization techniques and organizes them onto an information Periodic Table. The method used consists of a metaphor of the chemical Periodic Table.

The principles of organizational structure that the authors in [1] made use of are:

- **Complexity of Visualization:** low to High, referring to the number of rules applied for use and/or the number of interdependences of the elements to be visualized.
- **Main Application or Content Area [how?, what?]:** Data, Information, Concept, Metaphor, Strategy, and Compound Knowledge. Furthermore members of this group can also be ranked according to their knowledge intensity, ranging from explicit, objective knowledge visualizations (such as, Data Visualization) to more tacit, subjective knowledge visualizations (such as, Compound Knowledge Visualization).
- **Point of View [when?]:** detail (highlighting individual Items), Overview (big picture), Detail and Overview (both at the same time).
- **Type of Thinking Aid [why?]:** Convergent (reducing complexity) vs. Divergent (adding complexity).
- **Type of Representation [what?]:** process (stepwise cyclical in time and/or continuous sequential), Structure (i.e., hierarchy or causal networks).

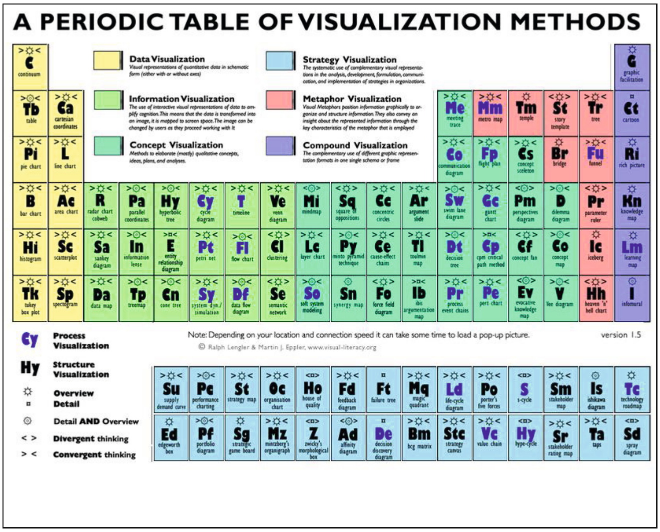

Fig. 2. A Periodic Table of Visualization Methods

In Fig. 2 the visualization model for the Periodic Table information proposed by [1] is shown. The Periodic Table makes 100 information visualization methods available in one unique figure (illustrated on the Periodic Table), by positioning a symbol for each method and its name underneath the symbol. By positioning the mouse on the method, the information visualization Periodic Table shows a corresponding example of this method. The table has two labels for the information visualization organizational methods criteria, used in the structure of this meta-model.

However, the table does not allow for any direct research by the name of a certain method. As there exists only a single image across the whole table, the search for a certain visualization method through its name is not a simple task, as the user needs to make a method by method visualization to search for the desired name. There also does not exist any interaction to show only corresponding visualization methods to a particular category or methods that meets some determined criterion.

The organizational feature of the Periodic Table positions the visualization methods that possess similar features and goals, closer to one another. Such a strategy facilitates the categorization of the visualization methods in a static form, mainly when it comes to the classification through the “Main application or Content area”. However, from the use of this model there exist difficulties in the information search, like when the user desires to research various criteria simultaneously, as in the following situations: to obtain all visualization methods, those being "Visualization Concept", "Detail and Overview", "Visualization Structure" and "Divergent Thinking".

Thus, besides having a slow search, the model does not make an interactive form available for obtaining results in a manner which visually separates them from other information available on the model.

The information visualization Periodic Table, uses the area color and position criteria to differentiate the categories of "Main Application or Content Area", symbol color is used to distinguish the principle of "Type of Representation" along with symbols to distinguish the principle of "Point of View" and "Type of Thinking Aid". Various visualization techniques were used to classify the visualization methods in accordance with the criteria used in the Periodic Table metaphor, but the process becomes complex, as it does not facilitate in the model search during the information visualization.

In carrying out consecutive method searches through the use of these symbols, the user may become confused over the search method criteria, mainly when the method symbols are similar, although the symbol criteria are in fact distinct.

3 Proposed Meta-model for Information Visualization

This section has as its purpose to present a meta-model proposal for visualizing the best visualization method to be used in the handling of information.

3.1 General Vision of Treemap

Treemap consists of a visualization form for the information created by Shneiderman [3] in 2006, which is capable of organizing the information in a hierarchical structure, through the use of the principles within the information itself.

This structure permits rapid information access, in visual form, separating the most important information or most favoured after the search, in a strong interactive process.

The user can separate the information in accordance with various visual criteria, as for example: position, area, color and texture. Fig. 3 shows an example of Treemap where the structure is directed by the criteria of position, color and area of the "Concept Visualization". It is possible to determine a structure in the form of a tree for search criterion. In regards to Fig. 4, the tree structure shows the structure directed by the search criterion through the Treemap group.

The Treemap structure allows greater availability of diverse visualization forms for the separation of the information in accordance with data search criteria. This type of arrangement facilitates the interaction in accordance with the user's visual needs, when it comes to the diversity of choice for the visual forms. For example, it is possible to highlight specific information according to colors or the same information according to area, for color-blind users. In this manner, the Treemap has various visualization forms obtained through optimized paths, enabling greater perception and interaction with the users.

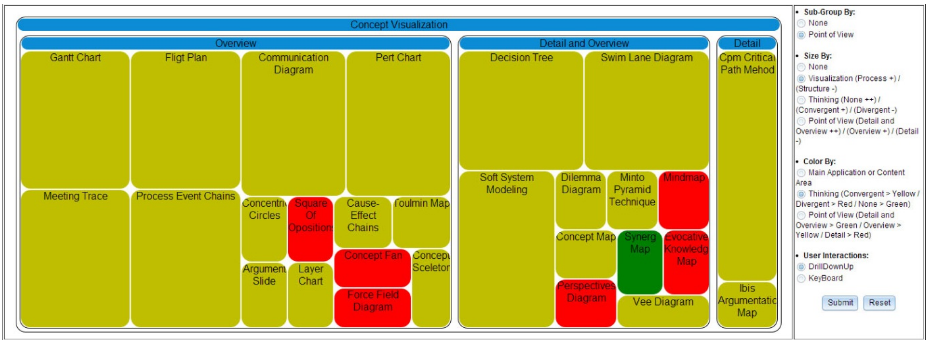

Fig. 3. DrillUpDown of "Concept Visualization"

3.2 Information Visualization Treemap

The information visualization meta-model of the Periodic Table proposed in [1], was converted in this study into a Treemap meta-model for information visualization, but maintaining the structure and organizational principles. The interactive process of pointing and selection of a method to show an information visualization example, which corresponds to this method, is maintained.

The captions were substituted for an interactive search with the user, which permits the choice of criterion that should generate the Treemap visualization form.

The choice of criteria that defines the information visualization forms is important for achieving the most adequate search definition, along with the perception that the user desires. In this meta-model some criteria can be used to define the information search for more than one of the principles used to categorize the information visualization models. For example, it is possible to search for the "Point of View" principle through the use of any of the search criteria, but the position criterion is sufficient for organizing the "Main Application or Content Area" principle.

For those principles which contain various types it is necessary to associate the variation to the criterion. For instance, the criterion of color for the "Type of Thinking Aid" principle possesses yellow variations for "Convergent", red for "Divergent" and green for "None". The area criterion for the "Type of Representation" principle has the greatest covered area of variations for "Process" and least covered area for "Structure".

Besides this, another possible interaction that facilitates information visualization consists of the *DrillDownUp* or *Keyboard* mechanism. In (tens, hundreds or thousands), this recourse makes it possible to show only the information group of interest, as illustrated in Fig. 3.

Presented in Fig. 10 is the Treemap information visualization model proposed in this study. The model groups, by default, the methods for "Main Application or Content" and allows for user interaction. In the example given in this figure, the user requested the separation into sub-groups by "Detail and Overview", size by "Visualization", on which the methods characterized with visualizations by processes

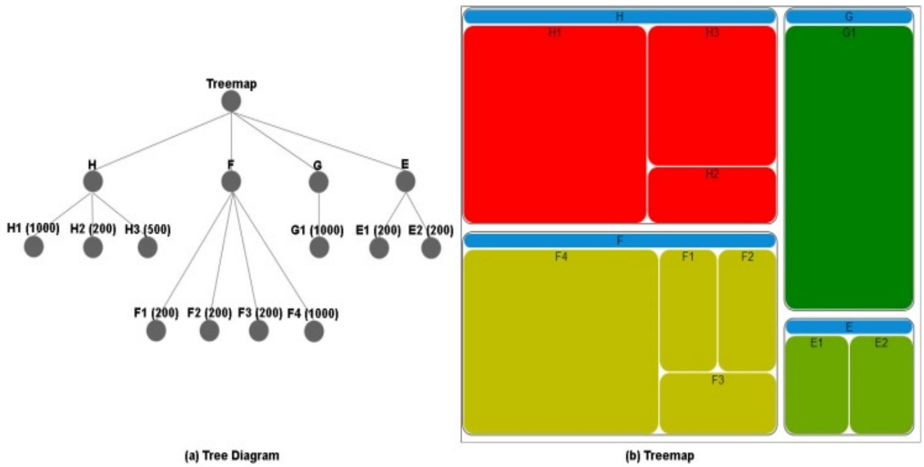

Fig. 4. Treemap structure example

Resultado do Teste

Number	Question	Answer	Expected Answer	Result	Answer Time	Visualization Information	Criteria
1	How many information visualization are there on the 'Information Visualization'?	18	18	Correct	2622	Treemap	group
2	How many information visualization are there on the 'Metaphor Visualization'?	9	9	Correct	2239	Periodic Table	group
3	How many visualizations of the 'Visualization' principle with the 'Process' type are there on the 'Strategy Visualization'?	8	8	Correct	2999	Treemap	group, (size - position)
4	How many visualizations of the 'Visualization' principle with the 'Process' type are there on the 'Concept Visualization'?	10	10	Correct	5833	Periodic Table	group, cor
5	How many visualizations of the 'Thinking' principle with the 'Divergent' type are there on the 'Concept Visualization'?	6	6	Correct	2435	Treemap	group, (size - position)
6	How many visualizations of the 'Thinking' principle with the 'Divergent' type are there on the 'Strategy Visualization'?	6	6	Correct	6332	Periodic Table	group, symbol
7	How many visualizations of the 'Point of View' principle with the 'Detail' type are there on the 'Concept Visualization'?	2	2	Correct	2792	Treemap	group, color
8	How many visualizations of the 'Point of View' principle with the 'Detail' type are there on the 'Information Visualization'?	1	1	Correct	5353	Periodic Table	group, symbol
9	How many visualizations of the 'Point of View' principle with the 'Detail and Overview' type, the 'Visualization' principle with 'Structure' type and 'Thinking' principle with the 'Divergent' type are there in the 'Concept Visualization'?	3	3	Correct	3335	Treemap	group, (size - position), color
10	How many visualizations of the 'Point of View' principle with the 'Detail and Overview' type, the 'Visualization' principle with 'Structure' type and 'Thinking' principle with the 'Convergent' type are there in the 'Concept Visualization'?	4	4	Correct	4593	Periodic Table	group, symbol, color
11	How many visualizations with the 'Point of View' principle and 'Overview' type along with 'Thinking' principle and the 'None' type are there in the whole model?	10	10	Correct	2719	Treemap	(size - position), color
12	How many visualizations with the 'Point of View' principle and 'Overview' type along with 'Thinking' principle and the 'Divergent' type are there in the whole model?	8	8	Correct	3977	Periodic Table	symbol, symbol

Thank you for your co-operation .

Fig. 5. Test Results – Answers to Questionnaire

are larger in size than those classified by structure. The color criterion was used to separate the information for “Thinking”, on which the yellow color methods correspond to “Convergent”, red to “Divergent”and green to “None”.

Therefore, to obtain all the visualization methods that are "Concept Visualization", "Detail and Over view", "Visualization Structure" and "Thinking Divergent", it is necessary only to search within the "Concept Visualization" group and the sub-group "Detail and Overview", for those methods that possess small area and size along with the color red. In a single visualization it presents all the methods through the criteria selected by user interaction. However, to facilitate the visualization of a specific method set, it is still possible to use the interaction facilitator mechanism of *DrillDownUp*, by clicking twice on the group of interest "Concept Visualization" or on the associated sub-group of interest "Detail and Overview".

4 Analysis of Test Results

To verify that our treemap representation is better suited for the task at hand, namely finding a suitable IV with given constraints, we performed a controlled user study in which

The evaluation of IV techniques is necessary for verifying the efficiency of such techniques when it comes to user support tasks, as well as to check their capacity for showing important information which facilitates the analysis, interpretation and comprehension of the data set. Such an evaluation is above all, important for the continued development of new techniques [6].

In this study, a web test tool was created with the aim of carrying out experiments and collecting data for the analysis of the results.

A user study was performed with 20 participants, of which 75% carried out the test in person and the rest realized the test online.

In the test, the user should answer 12 questions presented in Fig. 5. Where each question evaluates one or more visualization criteria. After answering all the questions, the system shows the result of the test along with the number of errors, the time spent to answer the question, the visualization meta-model and the criteria involved in each question.

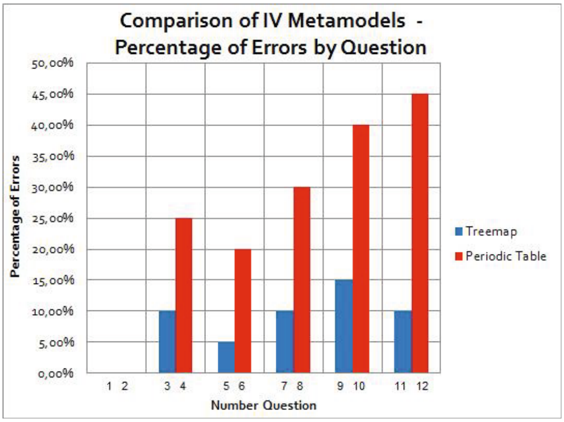

Fig. 6. Comparison between the Treemap and Periodic Table Meta-Models – Error Percentage per Question

Besides this, the test was divided intercalating questions between the Treemap and Periodic Table meta-models, albeit, the odd numbered questions refer to the Treemap and the even numbered questions refer to the Periodic Table.

The error percentage for each question is presented in Fig. 6. Therefore, it is possible to carry out the comparison between the errors generated for the Treemap and Periodic Table meta-models. The first two questions are simple and therefore did not result in errors during user tests. One observes that in all the questions, the Treemap meta-model obtained the best result, when compared to the Periodic Table meta-model.

In Fig. 7 the percentage error result for each of the two meta-models are presented in accordance with the criteria used in the tests. The evaluated criteria were: color, symbol and size or position, where the Treemap meta-model does not use the symbol criterion and the Periodic Table meta-model does not use the size or position criterion.

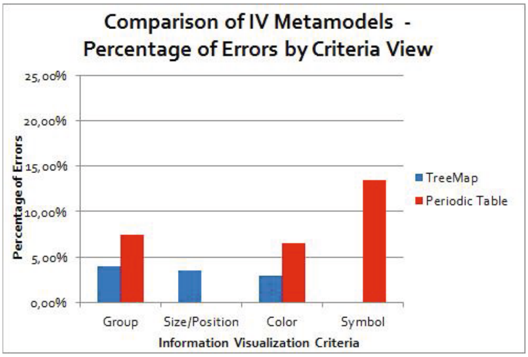

Fig. 7. Comparison between the Treemap and Periodic Table Meta-Models – Error Percentage by Visualization Criteria

Through the use of the results, one can verify that the Treemap meta-model achieved, in all criteria a lesser error percentage than the Periodic Table meta-model. Besides this, a criterion by criterion analysis can be carried out where one sees that the criteria of color and size are better, in terms of human perception than the criterion of symbol.

By using the calculation for, time spent to answer each question, it is also possible to evaluate the human perception time for each visualization model.

In Fig. 9 the human perception time spent to answer each question is shown, based on the tests carried out. One observes that the time spent to answer all the corresponding questions for the Periodic Table, is greater than the time spent to answer the questions in Treemap. Concerning questions 11 and 12, which compare symbol criteria from the Periodic Table, the time spent is logarithmic for Treemap and linear for the Periodic Table. This is due to the fact that to find the answer to question 12, which refers to the Periodic Table, the user needs to go over every element in the model.

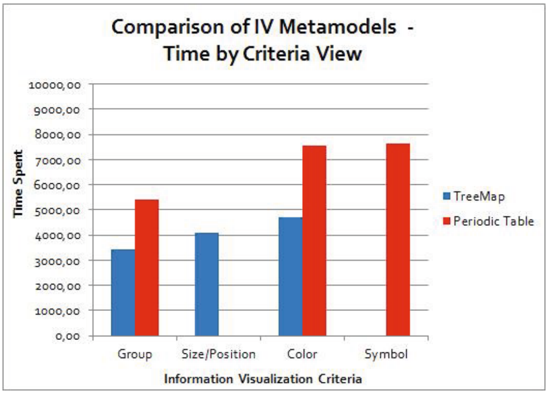

Fig. 8. Comparison between the Treemap and Periodic Table Meta-Models – Answer Time per Criterion

Another possible analysis that may be verified, as shown in the graph of Figure 8, was made in relation to the time spent to answer the questions by criterion for information visualization. One observes that the higher response times for perception were spent for the criteria of color and symbol, due to the user confusing the color or the symbol to be verified. The least response time was spent for group criteria, due to facility in the information search process by use of this criterion. The criteria of size and position obtained similar results. In this other graphic visualization one is also able to verify that the time spent for answering in the Treemap meta-model in all criteria is less than the Periodic Table meta-model.

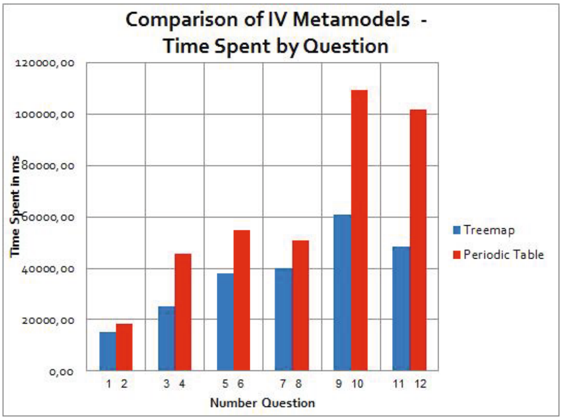

Fig. 9. Comparison between the Treemap and Periodic Table Meta-Models – Answer Time per Question

5 Conclusions

The information visualization criteria make the identification and the information search possible, through the organizational structure of the visualization methods.

This article proposes an information visualization meta-model based on Treemap logic structure, which is inspired upon the organizational structure of the proposed Periodic Table model of visualization methods.

The results show that the structure of the innovative proposal allowed for a interactive search which is of easy use for carrying out research for the most adequate methods, when solving information visualization problems.

Some of the visualization criteria are more perceptive than others. Therefore, it is possible to determine the time complexity of the algorithm for the meta-models as well as for the information visualization models, from the visualization criteria they use. This method makes it possible to anticipate performance problems and expressiveness by choosing the most appropriate method for information visualization prior to its implementation, ie, during its analysis.

This is measured by a method created in this study denominated as analysis of visualization algorithms, analogue to the method of analysis of computational algorithms. In agreement with the experiments carried out, one observes that the Treemap based visualization model, is more efficient and expressive than the Periodic based meta-model, when the color and group visualization criteria are considered. Besides this, the experimental results show that the algorithm analysis method can be applied to information visualization.

The proposed meta-model possesses the criteria of position and size that were evaluated showing good results in terms of the capacity to abstract and distinguish these through human perception. The visualization criterion by the use of symbols that the Periodic Table meta-model proposes, obtained worse results in relation to other criteria. This was due to the fact that the users on various occasions became confused, when selecting the symbols during the information search.

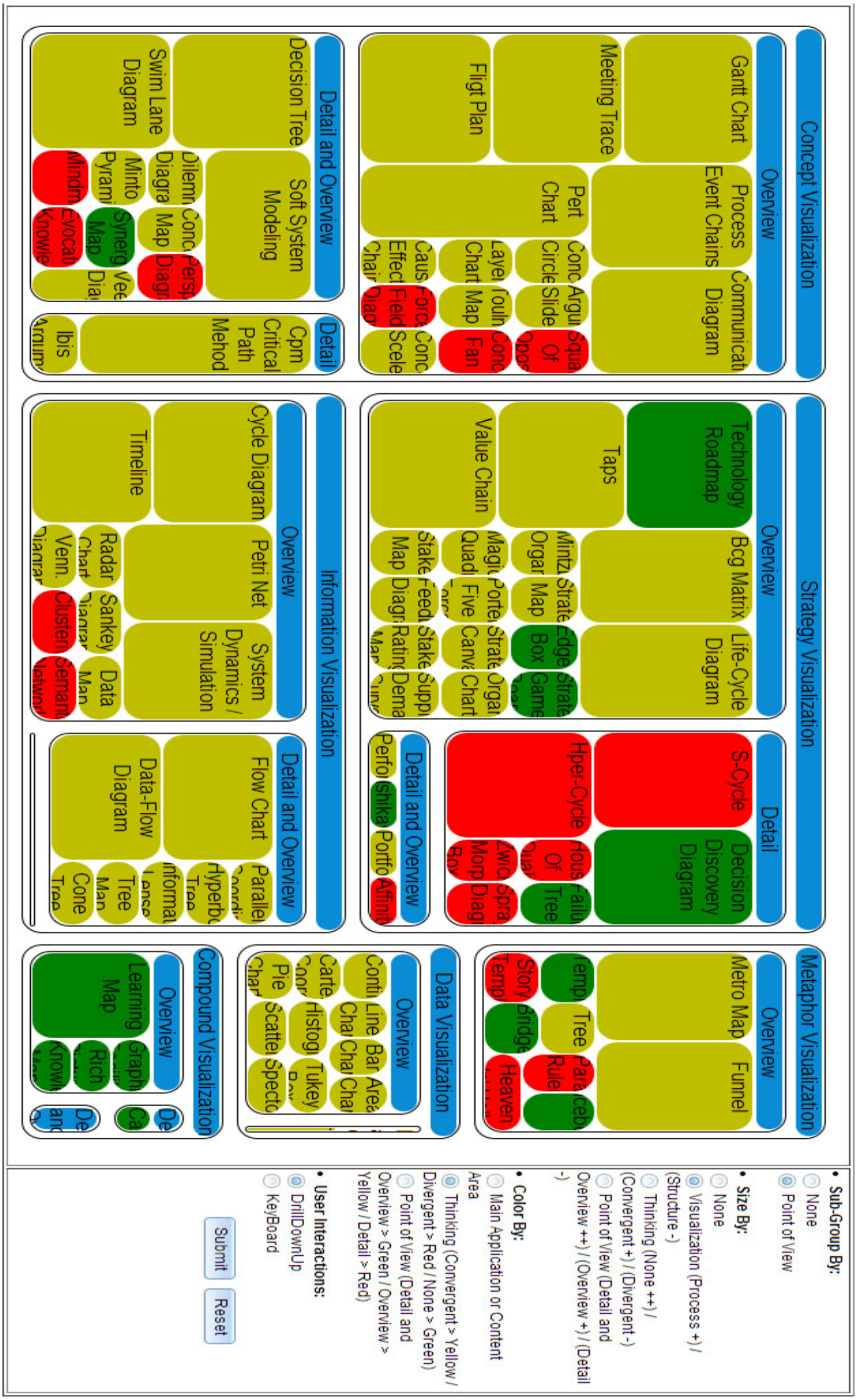

Fig. 10. Treemap meta-model for Information Visualization

It has therefore been concluded that the proposed structure gives users the facility to understand and search for representations and information that they express, by use of the proposed Treemap based visualization meta-model.

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