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Concept-Sketch: A Tool for Cooperative Visual Analytics*

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Visual analytics is a newly built field rooted on information visualization. By using information visualization, data mining, human computer interaction and other techniques, visual analytics can support reasoning process and decision making activities. In a cooperative environment of visual analytics lifecycle, the ability to recognize users and their intention intelligently and effortlessly during the visual analytics process is important. Due to its intricate nature and limitation of interaction, it is difficult to extract and communicate a concept based on specific and various users' requirements. In this paper, we present the framework for creating and modifying a concept map by an intuitive sketch interface that allows analysts to collaborate and utilize live collection of enterprise data in a visual interface. A user model is given to support collaborative analysis based on modeling users and tasks visual analytics. Furthermore, we propose the algorithm of concept map layout to facilitate the visual analytics. The interface presents the analyst with the dashboard configuration of certain data that users deems relevant, provides tools to facilitate the decision making process. Finally, we apply it to a collaborative visual decision support system. Experimental results show that it enhances the accessibility and the individualization of collaborative concept map for configuring enterprise data and helps to enhance user experience during the visual analytics process.

Keywords: visual analytics; concept map; cooperation; sketch based interface;user interface.

1. Introduction

Enterprises generate, summarize, and disseminate a large and increasing volume of abstract and statistical data that can be linked for decision making. The visual analytics presents a clear picture for representing and configuring those data. The application domain of visual analytics has emerged over the past few years dealing

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with the analysis of data involving humans. This domain covers, among others, information visualization and knowledge mining. The strong interest in this domain has been motivated by the desire for improved human-computer interaction for which there are many promising applications. A significant issue faced by many visual analytics systems is to provide the individual data representation for decision making based on the collection of requirements as users describe intention and observations from the environment.

Sketch is a flexible and natural tool for thinking, reasoning and communicating. It has been proved that because of the short term memory of human, it's very essential for human to embody their kinds of conception[1]. First, sketch is intuitive. It can present a group of concepts by its initial status, and the actual intention is also shown. Second, sketch can support a gradual improvement of representation, which is similar to the process of user reasoning. Third, Sketch itself has an abstract characteristic. It can ignore the redundant information and only keep the main branch. Comparing with traditional WIMP interface, sketch interface, which using electronic pen as the input device, is a better choice when we want to show concepts and make decision.

Decision making process is the most important thing during the whole management lifecycle[2]. If managers can deal with problems properly, companies can develop stably. In Simon's Decision-Making theory, he divided the decision making process into several parts, and defined it as a cycling process. It is important for a company to provide a tool to support the decision making for its development. Portfolio management system, Brandaid, Projector are three kinds of decision making systems. They are widely used in many different domains, such as finance, advertisement, etc. With the development of decision making systems, information visualization systems and visual analytics systems were used to enhance the cognition ability and accelerate query.[3] The technologies of visual analytics facilitate the decision making process and lead to the effective results. However, it is often the case that for current systems either there is insufficient users' intention representation in the process to produce confident analysis results, or, especially in the case of cooperative operations, the natural and simple interactions are needed to facilitate the process.

In this paper, we provide the related work about current sketch based system, visual analytics system, introducing the aspects of collaborative operations and interactions. In section 3, we introduce the collaborative concept map and the sketch based user interface. In section 4, we give a model for users and tasks during the visual analytics process. Furthermore we present an algorithm of layout of concept map to facilitate the representation of users' intentions in section 5. Then a prototype built on our own engine is shown to demonstrate the algorithm.

2. Related Works

Many works have been done about information visualization and visual analytics systems. ComVis[4] is a multi-view visualization system. It can support interactive refresh between views with the same datasets. Prototype on medicine area can be quickly implemented using this system. But collaboration between users is not provided. Many Eyes[5] is a web-based visualization system developed by IBM. It can construct simple visualization web pages in many kinds of view rapidly. It also provides online chats to support collaboration. But its collaboration is too simple for users to use. Users can't communicate and share with each other only by online chats. CoMotion[6] is an excellent visualization system provided by Maya Vis. It has been used in many kinds of areas such as Business Intelligence, military strategy, etc. It has abundant interaction technologies, and support collaboration too. But its construction process is a little too complex. All these three systems ignore an important issue. They paid little attention on the decision process of a user or multi-users. Decision process is an analytical reasoning process. Systems which can support reasoning process and support tools for noting the process is much more suitable for information visualization and visual analytics.

Many diagramming techniques have been developed to facilitate the reasoning process, such as mind maps, concept maps, cognitive maps, etc.[7,9] Concept Map[8] was firstly presented by Joseph D. Novak. It's a graph which uses nodes to represent concept and edges to represent relationships. Initially it's used in education and had a great success. Now it has been used in many kinds of areas. Yedendra B. Shrinivasan[7] brought it in information visualization and proposed an information visualization framework which can support reasoning process. It has three views: data view, knowledge view and navigation view. Concept map has been added into the framework. This is a novel and useful attempt on this area. However, this framework is not very good enough on these issues. First, multi-user reasoning process is necessary enough in collaborative environment, but it doesn't support. Second, it has only one kind of visual component, this is far from enough in decision making and reasoning.

Sketch is a popular tool for interactively design in different domains such as animation, garment design, mathematics sketching, botanical modeling, hair style modeling, and floral modeling. Turquin of Brown University shows a method for simply and interactively creating basic garments for dressing virtual characters. The user can draw an outline of both sides of the garment, then the system makes reasonable geometric inferences about the shape of the garment[10,11]. Takeo Igarashi gives interaction techniques for putting clothes on a 3D character and manipulating them[12]. The user paints freeform marks on the clothes as well as on the 3D character; the system then puts the clothes around the body so that corresponding marks match. In these systems, sketching can be used to create the prototype of design quickly. Recognizing and understanding of sketches can be performed based on domain knowledge.

There are some researches on collaborative analysis systems[13-18]. One kind of architecture on collaborative visualization system is shown below. The main components of this kind of system are collaboration server, copy of image, and visualization system. It's a general architecture on collaborative visualization. Systems like COVISA, COVISE, CUMULVS, ICENI, MANICORAL[19-24] supports collaboration. They are different in number of users, access control and so on. They don't do well in user interaction and don't have a theory support on analysis process.

Based on what we have found in disadvantages of current visual analytics systems on collaborative operations and interactions. We firstly give a model for users and tasks during the visual analytics process, and the cooperative concept map is presented to help construct the analysis environment. After that, we present an algorithm of layout of concept map to facilitate the representation of concept maps and deduce user operation. Finally, we implement a prototype to shown the theory and algorithm we have proposed.

3. Overview of the Concept Sketch

Concept map is developed by Joseph Novak and his research team at Cornell University in the 1970s. It's used for representing the emerging science knowledge of students initially. Then it spread around the world. Just as we said, sketch is natural, intuitive, and easy to understand. Using sketch as the presentation tool of concept map is a good method. Sketch based interface is an intuitive interface for computer user interface. It is operated mainly by natural gestures to give commands to system, and shows a user friendly interface which is similar to what is written on paper. In this section, we show the collaborative concept map and the natural interface under sketch theory.

3.1. *Collaborative Concept Map*

Collaborative concept map is made up of nodes and edges. Each node means a concept, and edges between nodes are the relationship of them. We refine the definition of concept map into our visual analytics. It's combined with nodes and edges. Each node represents a target or a sub-target which user need to analysis. Each edge means the relationship of interaction or branching.

We bring in the concept map for our analysis process. During the early phase of making a decision, it is used to provide an overall structure for certain task scene in a natural way. We define each node as a target, and edges from one node to another means target to sub-target. A simple collaborative concept map is shown in Figure 2 as following. The following concept map is the collaboration of solving a production problem of a sewing factory. Cooperators construct the concept map together, different users have different view. Figure 2 is the view of a certain user. To solve the problem, cooperators divided the target into sub-target and then divide more. Each target is presented as a node. This concept map shows collaboration status in different color and size. Nodes with different color represent different users or different group of users. Color with gray is the current user's operation and creation of nodes. The rectangle node means it's not edited collaboratively. The ellipse node means the node is edited by two or more users. So communication between users is necessary now.

During the collaborative construction of the concept map, operation of a user on the concept map can cause different feedback to other user's view.

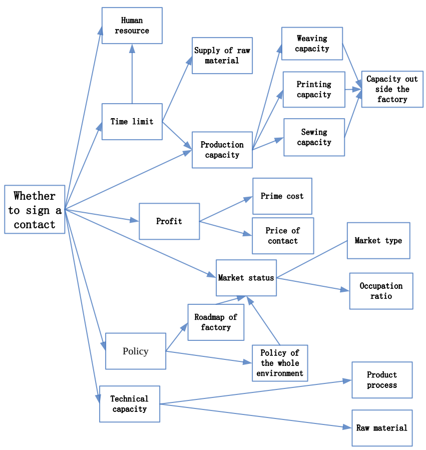


Fig. 1. A concept map.

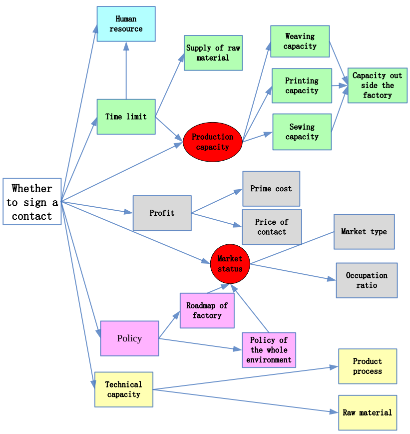
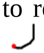


Fig. 2. A collaborative concept map.

3.2. *Natural Interface*

Decision making can be divided into two parts. One is general decision making, most of which is the daily routines. The other is creative decision making in case of emergency matters[2]. Using sketch to manipulate the information between users and computers is an effective way in decision making process, especially in creative decision making process. The sketch by user shows the intension of manipulating process and the organize method of reasoning.

Gesture is a group of meaningful lines drawn by user. It's a simple type of sketch. In collaborative decision making process using collaborative concept map described in section 3.1, the most important part is the manipulation of the collaborative concept map. Its manipulation commands can be mapped to gesture, and this is a good way because it's similar to user habit. We define the gesture and command mapping in Table 1. When we design the mapping relationship, we follow these guidelines. First, the gestures should contain part or all of the meaning of the operation, such as "Undo", "Redo" in Table 1. Second, the gesture should be as easy as possible, so user can easy to remember. Third, the structure of each gesture should be different. For example,  and  only differs in one geometry attribute, they should not appear in the same gesture set.

Besides using gesture to operate collaborative concept map, we provide an input panel which can recognize characters to let user input directly when editing the text of the nodes or edges. We provide some widgets such as pie menu, which is friendly to pen interaction, to adapt sketch interface for user to use easily. All the features are built on the platform we developed especially for sketch based systems. The overview of the platform is described in Section 6.

Table 1. Mapping between gesture and operation.

Gesture					
Operation	Undo	Redo	Delete (node or edge)	Create node	Edit (node or edge)

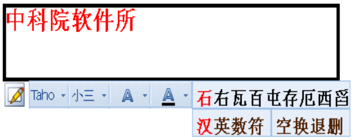


Fig. 3. Character input panel.

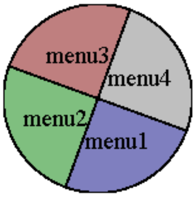


Fig. 4. Pie menu.

4. User Modeling

4.1. *Principles of Modeling*

Visual analytics tools can provide the intuitive, user-familiar representation out of abstract and complicated data. Its essential point lies on the advanced user interface which supports the more intelligent interaction. Based on the main characters, we focus on the following points for special and certain visual support in visual analytics.

(i) **User experience**. A good visual analytics system design needs consider all the requirements in the lifecycle of system development. User experience about the system is reflected from communication based on individual attributes, psychology, background, environment besides the affection of human information processing. How to efficiently provide satisfied user experience inside the usability of system and efficiently capture the user intent is a difficult problem. By modeling user, task and context in visual analytics system, it provides a natural and effective communication for improving user experience.

(ii) **Natural Interaction**. One of the ultimate goals for visual analytics system is to provide natural and intuitive interactions which are similar with and beyond those happen in real world, as reduce cognitive load of users and improve the efficiency. Multimodal interface is adopted to meet the requirements of conceptual design and mental model by mimicking the traditional human-human communication style. Multimodal interaction can to large degree support the input and output requirements intuitively instead of traditional input of keyboard, selection of menu and operation of mouse.

(iii) **Intelligent support**. Intelligence enhances its interaction ability in terms of context awareness. Systems can adjust behaviors based on different context, context change and context history to increase the conversational bandwidth between human and computer in visual analytics system. The user's continuous input goes with continuous visual feedback, which provides full interaction information through a user-friendly interface of capturing context and deliver it to interested users. It uses context to provide relevant information and/or services to the user, where relevancy depends on the user's task.

4.2. *Analysis of User Profile*

Pat Langley introduced the definition of adaptive user interface, "An adaptive user interface is a software artifact that improves its ability to interact with a user by constructing a user model based on partial experience with that user".[25] The user model represents the set of information needed to predict some user behaviors under a set of possible stimulations. As is known to all, users differ in many levels of characteristics and subjective needs. User model involves mental model and task model.[25,26,27] Mental model can be created in working memory based on concept, knowledge and current environment information from long term memory. Basically, mental model includes the information about objects, users, behavior and rules, facts and knowledge in memory. Given the exterior condition, the output of mental model should meet the real psychological responses. If the user model can match the conceptual model for system, it can avoid some certain operation errors and user mistakes for better efficiency and user experience.

M. Sandra Carberry ever pointed out that there were seven aspects involved in a user model[29], such as ability, knowledge, attitude, preference, goal, plan, and believe. A mental model and task model are given to deliver different aspects in a user model. In Table 2, we present the aspects involved in the mental model which can be described to include user general features, user skills, user preferences and special skills related with application, reflecting the characteristic of ability, knowledge, attitude, preference about users. Those aspects can be updated to reflect increases or changes in user knowledge of the application during the interaction.

It is unnecessary and impossible to make a system to satisfy all users. But the design of system should try to meet the requirements of most users due to their individuality. To know users well can lead to the goal efficiently. By modifying the profiles or preference, users can personalize their access to system during the operation process.

Table 2. Some characters in mental model.

<table>
<tr><td rowspan="3">User general features (basic attribute)</td><td>Gender</td><td>Age</td><td rowspan="3">User skills (ability to extend or deepen operation later on)</td><td>Knowledge level</td></tr>
<tr><td>Occupation</td><td>Location</td><td>Perception</td></tr>
<tr><td>Level of education</td><td>Others</td><td>Reasoning and analyzing</td></tr>
<tr><td rowspan="3">Special skills related with application</td><td colspan="2">Proficiency about the devices or the systems</td><td rowspan="3">User preferences (individual requirements)</td><td>Operation preferences</td></tr>
<tr><td colspan="2">Experience about similar tasks</td><td>Content preferences</td></tr>
<tr><td colspan="2">Knowledge about the system</td><td>Layout preferences</td></tr>
</table>

4.3. *Task Model of Visual analytics Process*

We also need to model the task of visual analytics and decision making process, especially in collaborative environment. Pirolli[30] and Thomas[31] have done much on the task modeling in analytic activity. They divided the visual analytics into two loops, that is foraging loop and sense making loop. They pointed out that the whole process is a loop. Based on their theory, we define our task process as shown in Figure 5. We will perfect it on overview and especially on collaborative support.

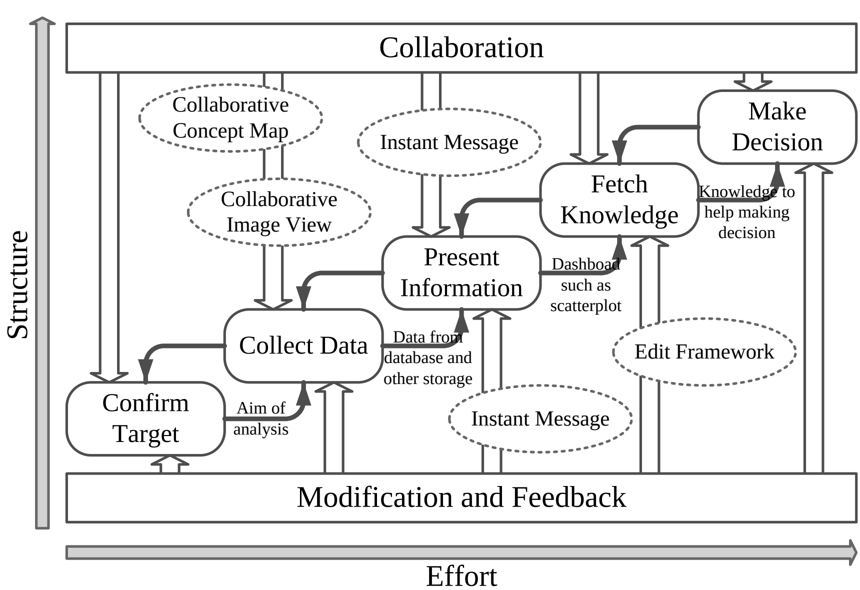


Fig. 5. Visual analytics loop.

We define our analysis loop in Figure 5. In our model, we add an overview task in the analysis and decision making loop. This overview task is not the same as what this appears in the Overview + Detail theory. It's a separate task. When the analysis loop starts, decision makers should first know what they want to solve, that is the main target of the process. Then he can construct the overview of the target (concept map in this paper). For example, he can divide one target into several separate sub-targets, and then sub-sub-targets, and so on. All the targets and sub-targets should have their data source to do the target. After the overview task, decision makers can do the rest things. Collect needed data to prepare for the presentation. Then choose the proper metaphor to present information. After that, users can get knowledge what they want. Then the decision is made by the knowledge and the initial concept map. The whole process is an interaction process, and each task can go back to the former task, and vice versa. During this process, users have to cooperate with each other, then give and get some modifications and feedbacks.

If the decision is hard to make or the task is too complex for one person to work out, collaboration is much more imperative. In this case, the collaboration of overview task is much important than other steps. And the concept map in the overview should be modified from time to time. In order to perfecting the overview task and simplify the rest task. We especially describe the task of the concept map constructing. In a collaborative environment, there are several users who play different roles and have different right in the decision making process. The target also will be divided into several sub-targets and sub-sub targets. To construct an overview concept map, users can add a target node, delete a target node and modify a target node. Add a target node is to add a sub-target, which might be a dataset to be visualized. It also might be a task to ask someone to work out. In the collaborative environment, communication is necessary, and of course delete target nodes happen from time to time. The most important task in the construction is the modification of the target node.

In the task of modification, there are several tasks to deal with. Discuss to dispatch target or sub-target to proper person to deal with, or let them to work together to overcome this target. Then user can forge data and add the useful data to the target node. After that, users can decide the proper dashboard and configure the data, interaction and other attributes.

During the process, users will communicate with each other and construct the overview concept. So communication is an important thing in the whole task. We define three of them: instant messaging, voice communication and collaborative viewing. Instant message is online chat tools like gtalk. Voice communication can be used by telephone and other tools. Collaborative viewing means one user can see what others do on the overview concept map, and the copy of image of their screen. Of course, all the tools and the result of them can be functioned by interaction.

5. Algorithms

In this section, we introduce an algorithm of layout of collaborative concept map to facilitate the representation of users' intentions. We divide this section into two parts. One part is some definitions and notations. The other is the description of the algorithm and pseudocode.

5.1. *Notation*

The construction process of concept map is also the process of construction of directed graph. We use a kind of force-directed based layout algorithm, which have put kinds of semantics into the algorithm. First, we have to model the semantics of the targets and their relationships. The semantics can be defined as a two-tuple group:

$$Semantic =< semanticType, value >;$$

We define each node is stressed by three forces:

(i) Repulsion force between each two edges, we call it CR. It's on the contrast to the distance of edges. In this force, Kc is a constant just like Coulomb force. Force of every two nodes can be shown in formula (1):

$$CR(p,q) = K_c \bullet (1/\left\|(p-q)^2\right\|) \tag{1}$$

The overall repulsion force of a certain node is shown in formula (2):

$$CR(p) = K_c \bullet \sum_{q\in \bar{P}} (1/\left\|(p-q)^2\right\|) \tag{2}$$

(ii) Attractive force between nodes which have edges with each other. We call it SP. The direction of one node is outward itself and follow the tangent direction. The force of each node is all the attractive force with nodes which have link with it. The formula of it is shown in (3):

$$SP(p,q) = K_s \bullet \sum_{i\in S} (w_i \bullet S_{pi}(semsim)S_{qi}) \bullet \left\|p-q\right\| \tag{3}$$

The overall attractive force of a certain node is shown in formula (4):

$$SP(p) = K_s \bullet \sum_{q\in E} (\sum_{i\in S} (w_i \bullet S_{pi}(semsim)S_{qi}) \bullet \left\|p-q\right\|) \tag{4}$$

In the above formula, Set E represents the set of point which has a link with point p. Set S represents the set of all defined semantics. S_{ij} means the set of jth semantics belongs to point i. w_i means the weight of ith semantics. K_s is a constant which seems like spring constant in Hooke's law. We also define an operation $(semsim)$. Its operational rule is as follows:

$$
\begin{array}{l}
\text{if}\,(S_{pi} = \varnothing \,\|\, S_{qi} = \varnothing) \\
\qquad S_{pi}(semsim)S_{qi} := 0; \\
\text{else} \\
\qquad int\ sum := 0; \\
\qquad \text{for each } s \text{ in } S_{pi} \\
\qquad\qquad \text{if}\,(s \text{ in } S_{qi}) \\
\qquad\qquad\qquad sum += 1; \\
\qquad\qquad \text{else} \\
\qquad\qquad\qquad sum += 0; \\
\qquad S_{pi}(semsim)S_{qi} := sum;
\end{array}
$$

(iii) A pre-defined direction constraint named TF. It's a constant.

$$TF = K_f \tag{5}$$

All the three kind of forces are vector with scale and direction. A certain node p will have the three kinds of forces:

$$
\begin{aligned}
NF(p) &= CR(p) + SP(p) + TF(p) \\
&= K_c \bullet \sum_{r \in P} (1 / \left\| (p-r)^2 \right\|) + K_s \bullet \sum_{q \in E} (\sum_{i \in S} (w_i \bullet S_{pi}(semsim)S_{qi}) \bullet \left\| p - q \right\|) + K_f
\end{aligned}
$$

After defining the constraints of the two kinds of forces, we need to describe the mass. means number of links of the jth semantics of node i.

$$m_i = \sum_{j \in S} (w_j \bullet n_{ij})$$

5.2. *Algorithm Description*

The pseudo-code of our algorithm is shown below. During the initialization of the algorithm, we need to layout every node except for the initial node randomly into the layout area. Then configure some constants and threshold of iteration. In the main loop, we calculate the force of every node by the formulas described above. Then calculate the acceleration by force and mass. After that, we can decide the shift of each node in the defined time step. The loop stops when the time of iteration is out of the threshold or the whole kinetic energy is less than a pre-defined threshold.

Algorithm:

```
set the init velocity of each node i    v(i) := (0,0);
set the location of the start node and randomize the location of other nodes;
set the time of loop    time := 0;
do
    TKE := 0;
    for each node n1
```

NF = (0,0);
for each node n2 != n1
NF := NF + CR(n1,n2);
for each node n3 connected with n1 by edge e
NF := NF + SP (n1,n3);
//constraints of direction
NF := NF + TF(n1);
*v(i) := (v(i) + TS * NF/M(i))*DAMPING;*
*position(i) := position(i) + v(i)*TS;*
*TKE := TKE + m(i)*v(i)*^{2}*;*
time = time +1;
while(*TKE* > ε or *time* < *M*)

The symbols in the algorithm are defined here:

CR(i,j): Repulsion force between i and j
SP(i,j): Attractive force between i and j
v(i): Velocity of i at a certain loop. It's a vector with scale and direction
TKE: The initial kinetic energy of the whole graph.
NF: Local variable. It means the overall force of a node
ε :The threshold of kinetic energy
M:Time of iteration
TS: Time stamps. It's used to calculate the shift
DAMPING: Damping. It's used to reduce the kinetic energy.0<DAMPING<1
position(i):Position of i. It's a vector with scale and direction
M(i):Mass of i

We show the force intuitively in Figure 6(a) means the initial graph (concept map in this paper) with five nodes. 6(b) describes and analyze the force of node p.

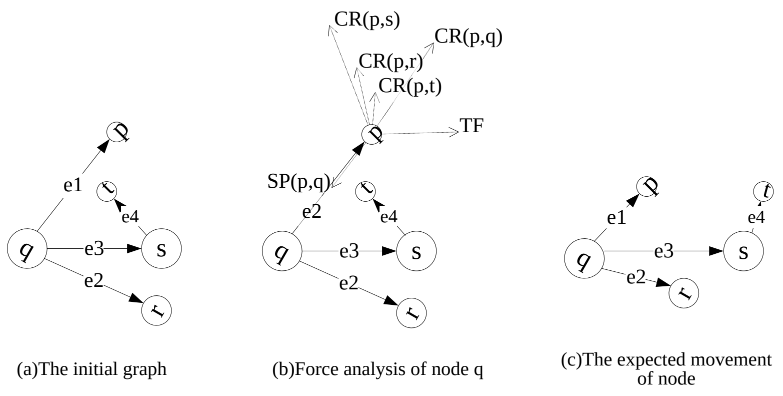


Fig. 6. Force analysis of node p.

Figure 6c describes the effect of the algorithm qualitatively. By the force it is taken, we can recognize the overall force of all nodes, all the nodes will finally come to a balance by the repulsion force and attractive force.

6. System Implementation

6.1. *System Architecture*

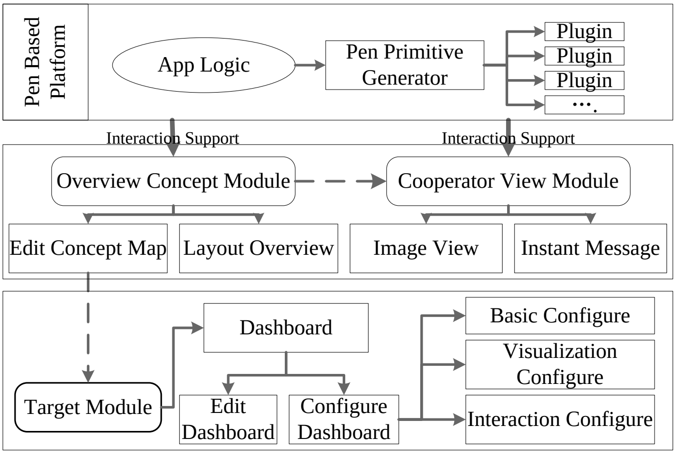


Fig. 7. System structure.

Based on what we have done in the former sections, we implement a prototype. The module structure of the prototype is shown in Figure 7. There are three main modules. The first of them is the overview concept module. This module can deal with the overview process, which we have defined in the former section. We use concept to implement this task of process. It contains edit the concept and layout the overview. During the using lifecycle of the overview process, user has to cooperate with others, so a cooperator view module is necessary. In this module, we provide image view and instant message to support the collaboration. Image view is what other cooperator's concept map looks like, it's a mirror of it. Instant message is just like gtalk using socket to transmit data and message from cooperators.

The edit of concept map also have to deal with specific target. Relatively speaking, target module is a separate module, when the editing of concept map invokes the target module, this module can work in its own interface and business logic. It's mainly job is edit and configure the dashboard. Edit means create a new metaphor, move, resize, delete and other basic editing operations. Another part is configuring the dashboard. We divide the configuration into three different and abstract parts. Basic Configuration configures the basic physical attributes. Visualization Configuration configures the visualization function of a dashboard, such as the mapping between data and graphical attributes. Interaction configuration configures the interactions between user and dashboards such as how to filter data in the dashboard, how to drag an element from one dashboard to another, etc.

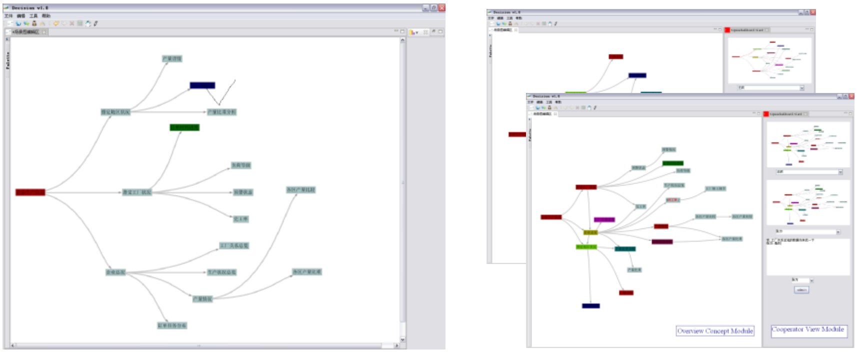
We design the overview concept module and cooperator view module using sketch theory. In order to implement a sketch interface, we use our own engine to implement this prototype. It provides the facility to generate pen primitive from a raw mouse or stylus events. During the generating any related feedbacks and active frame interacting will also be handled by the engine.

The engine can be divided into three main components: The pen primitive generator, the application logic and default implementations of all plug-ins.The generator accepts raw mouse events as its input. It outputs generated pen primitive. The generating process can be controlled by several parameters, which can be set at runtime. This component also defines the plug-in architecture. During the generating, it invokes plug-ins to display feedback. This component can be used stand alone, but it’s more convenient to work with the application logic and default plug-ins.The other components are based on the display function. The application logic, as the application’s entry point, feeds input to the generator, and also provides the display surface to default plug-ins. Default implementations of plug-ins handles feedbacks and will be set to the generator when initializing the application logic. These plug-ins are Cursor manager plug-in, which can load cursor resource and map each system depended cursor to a cursor ID in integer.Feedback effects plug-in, which draws dynamic feedback effects such as strokes and frame-lines. Active frame display plug-in, which draws the current active frame. Active frame interacting plug-in, which moves or resizes the current active frame.

6.2. *User Interface of Prototype*

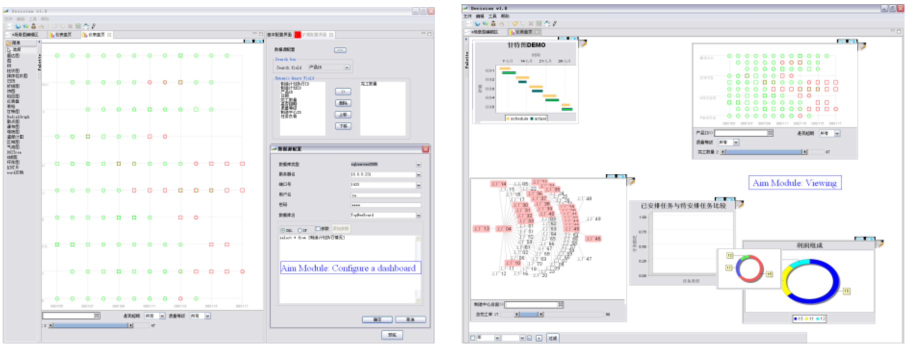
The interface of the prototype is shown in the following figures. Figure 8 is the Overview Concept Module. It’s a concept map what a user can edit it and add dashboard to a certain target. Both the operation can be done with defined gestures. The right part is Cooperator View Module. User can select two cooperators, and see what their concept map look like. This module has an instant message part for users to communicate with each other to dispatch target and configure dashboard. Figure 9 is module of a certain target. Figure9(a) is the interface of configure a scatter plot. We will configure its data source, its visual mapping and interaction with others. Figure9(b) is the interface of showing a target. It has five dashboards with it. A dashboard itself filters data in the surface. Interaction between dashboards can play an important role in the process.

The collaboration interface is shown in Figure 10. These two figures show Concept map collaboration and dashboard collaboration of different users. Figure10(a) shows the initial construction of concept map, User A use gesture  to add a target to the map. User B can get the change and shown in his own interface. Figure10(b) shows the interaction collaboration of dashboards. User A uses filters to filter data of scatterplot. User B gets the change and filters his own data.



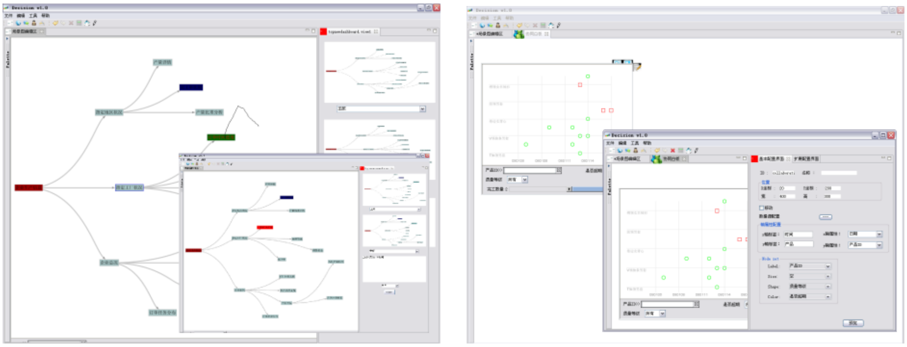
a. using gesture to edit node b. UI of overviewconcept module

Fig.8. Prototype: Overview concept module



a.configuration of a certain dashboard b. showing a target

Fig.9. Prototype: Configuration and Representation



a. Concept Map collaboration b. Dashboards collaboration

Fig.10. Collaboration interface for different users

7. Discussion and Conclusion

With the development and needs of visual analytics, more and more theories and systems come to the world. But many of the systems don't support collaboration well, theories on collaborative visual analytics are not sufficient neither. In this paper, we proposed a new visual analytics loop to perfect collaborative visual analytics, and we use concept map to support our analysis loop. In order to provide a more natural environment, we propose an idea of using sketch based interface to facilitate user interaction. Then we proposed a kind of semantics based layout algorithm to support collaboration well. Finally, a prototype is implemented.

There are several aspects to be done in the future. First, current sketch based interface is only implemented in overview concept module. The target module is also traditional WIMP interface. Second, though the semantic is contained in the map, it might be strongly coupled with specific domains. So a good definition of specific semantic is very useful. By doing these the layout algorithm will display better to the user. Another thing to do is model the data our theory and system support. By doing this we can use our system to support analysis and decision making better.

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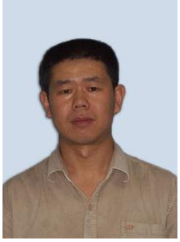

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