An Audio-Visual Information Visualization System for Time-Varying Big Data

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***Abstract*—**Nowadays, there are many methods proposed for helping users to efficiently find relevant contents on the Internet. However, there is still no guarantee for users to be always able to develop an appropriate perception/understanding toward the topics they concern in an efficient manner. To solve the above problems, we propose a novel visualization system which aims to improve users' perception efficiently through both audio and visual cues. Through our system, users can explore and manipulate data in an interactive and multi-resolutional manner. In addition, by integrating the concept of harmonic chords, our system auditorily represents certain structures of multiple data clusters chosen by users. Furthermore, our system highlights groups of related data in the information graph dynamically. This approach can help user to serendipitously find hidden data cluster with similar pattern of relationship.

***Keywords*—**Information Virtualization; Man-machine Interface; Semantics calibration; Wheel of Emotions.

***Abbreviations*—**Application Programming Interface (API); Hyper Text Markup Language (HTML).

I. INTRODUCTION

THE Internet has world-widely become an extremely vast source of information, new datum is exponentially created and accumulated day by day. How to help users find relevant content and understand its meaning in an efficient manner becomes a more and more important issue, especially in the field of Big Data. Several research reports have been published for effectively representing large-scale data with graph. For example, Yukio Ohsawa et al., [6] presented the KeyGraph algorithm to extract keywords representing a summary of the original point of a document; and Huang et al., [7] introduces a new model for Attributed Information Visualization that can be used to visualize the relational data with many associated attributes. Also, for user interaction, Abello et al., [11] proposed a visualization system based on node-link-based graph for interactive navigation of large graph; and Yu-Hsuan Chan et al., [12] introduced different representing styles of information graph and abstracted data by clustering related nodes and merging paths between related nodes.

There are several important issues remain challenging in the previous works. First, the extracted data and relationships may have different meaning to different users. The ideas/concepts with similar principal values to a user may be understand/accepted by himself/herself more easily. However, the above issues of customization and calibration are seldom discussed in the previous works. Second, the sensibilities of human work in a highly parallel way, but with a very limited number of focuses. To solve this problem, a multi-resolutional interface which hierarchically organizes data for visualization can be helpful for users to achieve the global and local perception respectively. In addition to the above structural information, other information such as the shapes, colors, and relative positions of nodes which used to represent data can also provide useful visual clues. Moreover, vision in cooperation with other senses, such as an audio-visual cooperation, may further enhance users' perception.

With the above considerations, in our previous research, we have proposed an audio-visual prototype of a novel visualization system, which aims to improve users' perception efficiently, in the APCEAS 2015 [15]. And in this paper, we further developed our system and adopted a novel data representation style. This new approach aims to provide an opportunity for users to find the hidden patterns of data relationship in an intuitive manner. The simple association rule method is utilized to extract and construct the relationships between data nodes; and a force-driven approach is used to determine whether two adjacent clusters are attracted, neutral, or rejected to each other. For calibration, The Wheel of Emotions concept is adapted into our interface for users to calibrate and customize the semantics of each keyword cluster in a simple and intuitive way [Robert Plutchik, 2001]. In addition to visual hint, the harmonic cord is played to highlight the data relationship changes as the time varies. With the pitches changed, users can understand that the data structure has changed and make a further observation. The combination of audio and visual sensibilities can also help users to find other possible patterns of relationships among multiple data clusters with similar structures.

II. Related Work

2.1. Association Rule

Association Rule is one important technique of Data mining [Usama M. Fayyad et al., 5]. It can be used to discover the interesting relationships among data. Following the original definition of Association Rule by R. Agrawal et al., [4] $A \rightarrow B$, consists of two parts: an antecedent item-set, A, and a consequent item-set, B, where $A \cap B = \Phi$.

In general, if $A \rightarrow B$, there are two constraints we can check for selecting interesting rules from the set of all possible rules, including:

Support: defined as the proportion of $A \cap B$ in the whole data item sets. In other words, it is the probability of A and B intersection, also written in $P(A \cap B)$.

Confidence: defined as the probability of finding the consequent of the rule in transactions under the condition that these transactions also contain the antecedent. In other words, it is the conditional probability, $P(B|A)$.

2.2. Emotion Classification

In 1987, Shaver et al., [3] classified the 135 emotion lexicons of lingua Latina into six basic types of emotions, including: Love, Joy, Surprise, Anger, Sadness, and Fear.

The psychologist Plutchik [8] purposed the Wheel of Emotions concept module which analogous the Color Wheel. The emotions on his module can be mixed to form another emotion just as the colors in the Color Wheel can be blended.

In this research, we adopt an extended module of the Wheel of Emotions, which consists of basic eight emotions and these emotions can be further divided into four pairs of opposite emotions, Joy vs. Sadness, Trust vs. Disgust, Fear vs. Anger, and Surprise vs. Anticipation.

In order to accurately align the psychological affections to different colors for each individual user, our system asks users to assign different color to corresponding emotion as calibration.

2.3. Eco-psychology and Eco-therapy

The eco-psychologist Gibson, J.J. (1979) focused his research on the visual perception of animals toward the environment. Animals can find the meaning of their around environment by interacting with it; and the environment provides animals with direct and efficiency perception information such as Vision or Audition. This interaction process allows animals to be able to know and learn the functions of targets. Later, based on the above proposal, the concept of affordance is developed [Agrawal et al., 4].

2.4. Gestalt Psychology

The Gestalt psychology's core concept is "the whole differs from the sum of its parts", that means human mind considers objects in their entirety before, or in parallel with, perception of their individual parts; suggesting the whole is other than the sum of its parts. Furthermore, the following six laws of perceptual organization are proposed Proximity, Similarity, Closure, Good Continuation, Common Fate, Pragnanz [Koffka, 1].

III. Concept and Implementation

The association rule method is used to construct a hierarchically clustered structure consisted of relationships and data which is extracted by utilizing the conventional web-mining and analysis processes. After then, the clusters of data are represented as nodes and deployed geometrically based on a force-driven approach. Meanwhile, the relationships between data clusters are represented as the edges of infographic. Both of the width of each edge and the length of distance between two data clusters can be used by users as a cue to recognize the strength of relationship between them.

More important, the above visualization methodology is further enhanced by adopting an interactive approach which enables users to calibrate and customize data semantics. In this paper our proposed interface adopts the concept of R. Plutchik's (2011) Wheel of Emotions Gestalt psychology to customize the polarity/tendency of each data cluster based on each user's psychological affection. Each cluster is associated to a color representing an emotion assigned by user. Then this association is used to determine whether two adjacent clusters are attracted, neutral, or distracted by each other. The deployments of clusters are recalculated and adjusted to better fit user's personal feeling.

According to the user's choices, our system auditorily represents certain structures of multiple data clusters by integrating the concept of harmonic chords. After users pick the certain clusters up, the distance between each two clusters determined by the interval between the pitches. Our system then plays the harmonic chords repeatedly per five seconds for auditory representing the relationships between these chosen clusters. Once the relationship data structure has changed or users are interested in different clusters, the harmonic chords will perform different pattern chord to hint that the trend of data has been changed. This approach allows users to keep one eye on the dynamics of time-varying data while continuing other works in parallel. Consequently, the resulting perception has a great potential for chance discovery.

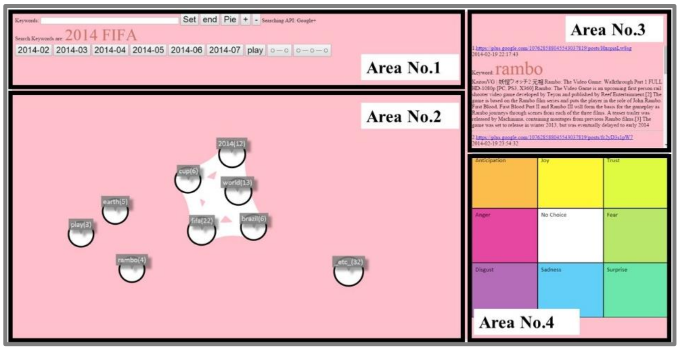

Figure 1: System Interface

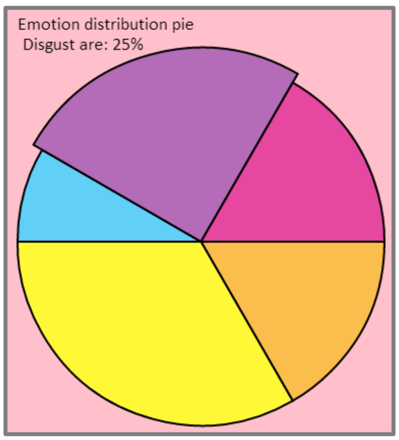

Figure 2: The Emotion Pie Charts

3.1. *Interface Designs*

As shown in Figure 1, the interface layout of our system can be roughly divided into four areas:

a. Area No.1: The searching area. When a user enter keywords into the text field, then push the "Set" button system will begin to search and visualize data clusters and relations. Push "+"/"-" button will zoom in/out area no.2, also, zoom in/out function can be performed by using mouse scroll wheel. After pushing "Pie" button, the area no.4 will display every emotion rate user applied on the emotion pie charts (Figure 2).

b. Area No.2 : Data visualization area. This area will display all the keyword group nodes and all data relation links. All the relations changes and updates will be presented immediately in this area.

c. Area No.3: Text data field. When user click the keyword group node, all the comments and keywords will be shown in this area. A page will show 10 comments, if there are over 10 comments user can click the "Next10" super link to update the page (Figure 3).

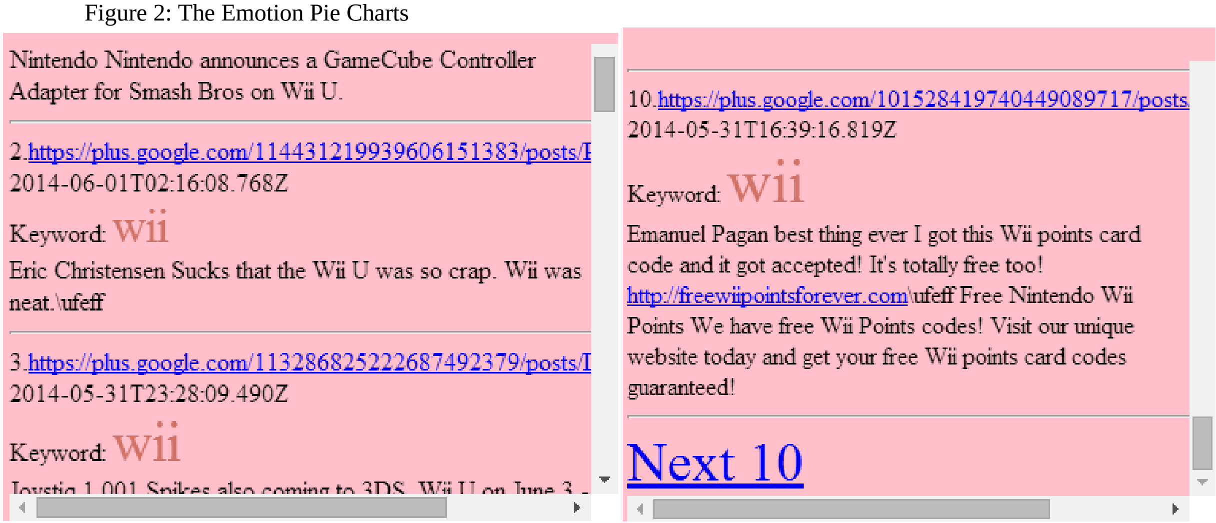

Figure 3: The Data Present Area

d. Area No.4：Drawing block panel and emotion pie chart area. Drawing block panel will be arranged according to user's initial emotion calibration mapping.

3.2. *Preprocessing of Google+ HTML API*

Our system utilizes the Google+ HTML API to catch people's ID, comment time and comment's content from the

Google+. Then, via a simple keyword analyse, point out the main keyword and delete nonsense words comment by comments. Finally, counting and sorting the keywords by appearing times and these comment data will display on the no.3 area mentioned in 3.1.

3.3. Relation Establishing

In 3.2 we count out the keywords of each comment, our system selects the most appeared keyword from all comments as main keyword for grouping clusters. Then, we will count the Support, Confidence value of each keywords. Then, we will count the Support, Confidence, Jaccard similarity coefficient and the Lift value of most top groups construct a relation table. The Jaccard similarity coefficient value is defined as the size of the intersection divided by the size of the union of the sample sets, that (A∩B) / (A∪B) [Bruce & Green, 9]. The lift is defined as two sets A and B, the probability of A,B union divide A and B set; or the conditional probability P (B|A) divide the set B probability, [Varmuza et al., 10]：

(1)

The relations between each cluster were established if Support value and Confidence value satisfied threshold.

3.4. Visualization

After logging in our system and calibration of the color and emotion mapping, all data will start to visualize. Every comment containing the same main keyword will be grouped together, and according to [Witten & Frank, 13], we set at most nine keyword groups to be shown in each level [George A. Miller, 2]. If there are over these nine groups will be arranged into the cluster named "etc". And each group will have at most nine subsets which is enclosed in each level as Figure 4 shown.

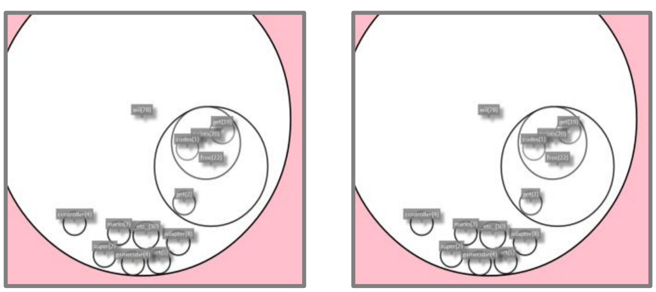

Figure 4: Group Level Presentation：1-level (left), 3-level (right)

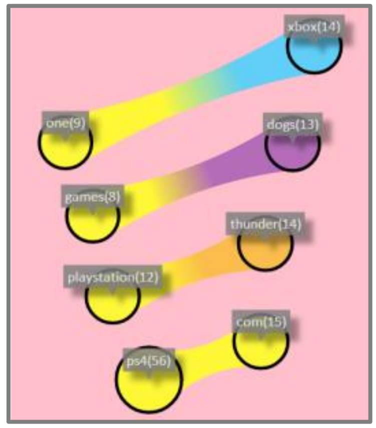

Figure 5: The Relation Attraction Force and Repulsive Force

According to the relation table that we count in 3.3, setting the relation if the Support and Confidence value over the threshold. In this research, we set the Support threshold as one over the displayed keyword group number, and the Confidence threshold as twice Support value. If a pair of keyword over these two thresholds, we set these two keyword group a relation link.

To utilize the Gestalt perceptual organization laws, we establish 3 kinds of force by force driven methodology. Including universal repulsive force, relation attraction and repulsive force and universal coulomb force：

a. Universal repulsive force：In order to avoid keyword group node from overlapping each other and let user able to observe the relations clearly, in the beginning, we set each keyword group node separated by diameter which is affected by the amount of data.
b. Relation attraction and repulsive force： Each pair of related keyword group node will interact according to color's relationship to emotions in wheel of emotions. If it's closer in wheel of emotions the attraction force will be stronger, two keyword group node gets closer; otherwise, if it is far in wheel of emotions the repulsive force will be strong; two keyword group node gets far.
c. Universal coulomb force：Each non-related keyword group node also according to the wheel of emotions, if it's closer in wheel of emotions we will set them more closely. And all moves satisfies the "Common Fate" law of Gestalt perceptual organization laws, as Figure 6 shown.

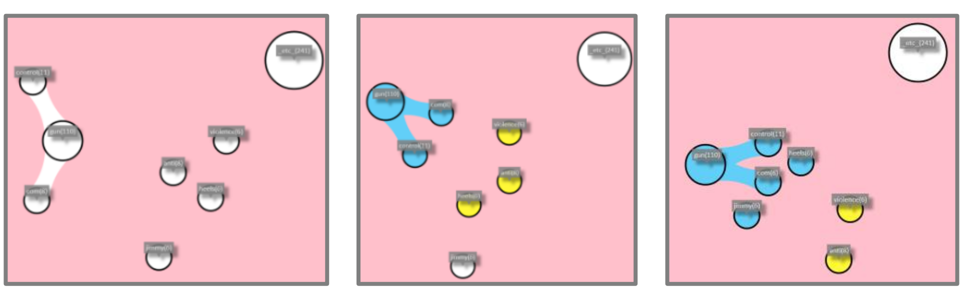

Figure 6: The Change of Emotion Aggregation Force

3.5. Record of Emotion Changes

In attitudinal consistency or the social desirability, the mixed emotion and emotion changes is two of important benchmark [Festinger, L., 1957]. In our system, users can review their own emotions assigning history of each keywords (Figure 7). After this process, users could recognized if they experienced cognitive dissonant or not [Irem Metin & Selin Metin Camgoz, 14].

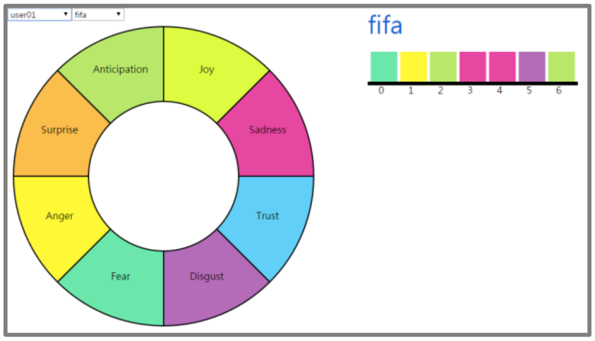

Figure 7: The Time Line of Emotion Changes

3.6. Sound

Our system will accumulate the keywords information in the last five months and classify the information by month. Our system provided users with two observing modes which users could pick up two or three different keywords as observing topic; the selected keywords will be outlined by blue or pink frame, as Figure 8 shown. Then, our system plays the harmonic chord per five seconds repeatedly according to the relation between keywords. The interval of pitches depending on the distance between two clusters. The longer the distance between two clusters, the more different pitches constructing the chord. And if the distance has been changed (including user click or change the clusters' color motion), the chord will also change.

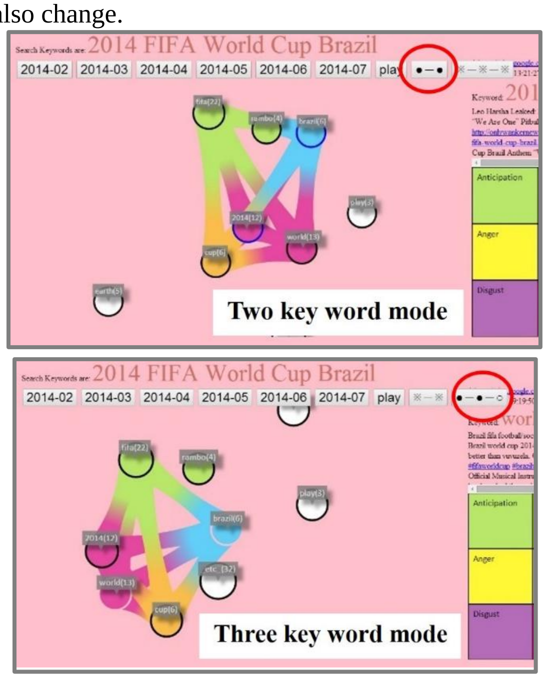

Figure 8: Using Two/Three Key Word Mode, Users Pick Up 2014 and Brazil

Moreover, when users focus on different month, our system would determine whether the selected keywords exist or not, if the keyword exist in the designated month, our system then play the harmonic chord which represented the distance of selected keywords. Therefore, when the selected keywords existed in the month which users paid attention to, users could observe the variation of clusters' relationship among different months by changing focusing month. Nevertheless, when the user pushes the "play" button, our system will play the melody with the classified harmonic chord which based on the relationship distance, and the related link and nodes will highlight that user can observe more easily.

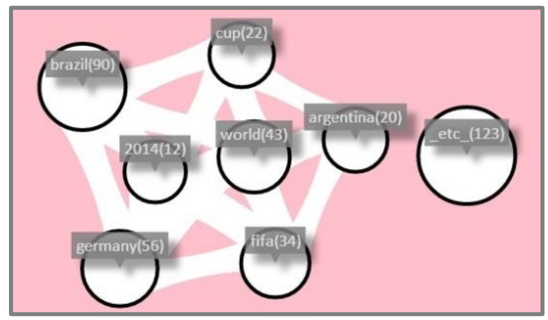

Figure 9: The Origin Data Relations

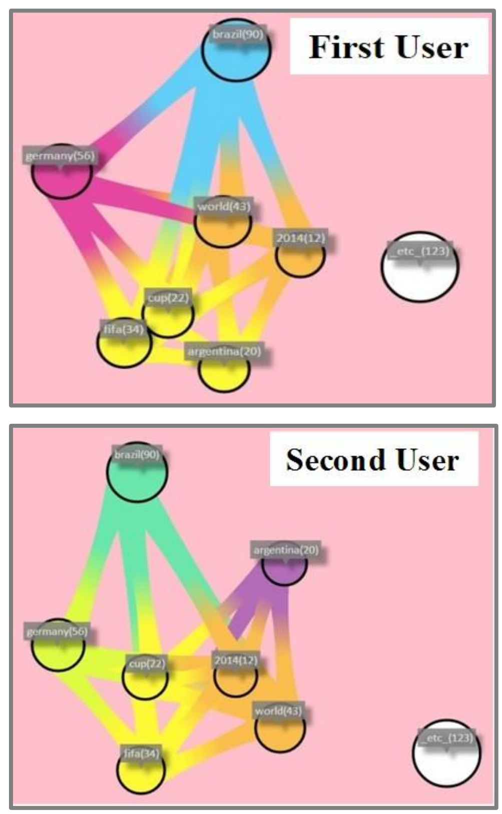

Figure 10: Color Mapping by First/Second User

3.7. Pattern Analysis

The relationship between two clusters consists of two components including force driven distance and color representing user's sentiment on the keyword. If user is interested in keyword A and B, which are assigned with complementary color. According to this pattern, user might discover the potential curiosity in another similar relationship and our system will recommend these clusters to user. For the purpose of highlighting pattern the user is interested in, we utilized Chiaroscuro method to brighten the chose clusters and darken the less interested cluster. However, the current results did not reach the expectation and couldn't find convincing pattern. We presumed that the possible reason for the result is the amount of data is not enough; so that the data relationship is not enough to analyse the pattern variation.

IV. Experiment Results & User Feedback

We chose one test from all experiments. And ask these two users searching about the 2014 FIFA world cup. Inputted keyword is "FIFA win", and the origin data relations as Figure 9 shown. The first user is an adherent of Brazil who gets a blood bath by Germany, and the second user is the Germany's fan. The emotion mapping as Figure 10 shown.

We invite 10 users to help us for questionnaire survey (as the following page), include lab member and information industry worker. In the questionnaire experiment, we set the non-drawable data visualization system as a control group. And make the T-test, set Strongly Agree +2 points, Agree +1 points, Neutral +0 points, Disagree -1 points, Strongly Disagree -1 points. Finally, we find out the all the P value of each question. The first question is "Is the relationship your own cognition or perception?", the P value is 0.014369；The second question is "Are you feel there are some keyword group more related?", the P value is 0.006721；The third question is "After the test, are you more impressed in the keyword group relationship?", the P value is 0.006721.

In general, if the P value lowers by 0.05, we say it's statistically significant difference; if the P value lowers by 0.01 is strongly statistically significant difference. By the T-test analysis, the questionnaire survey revealed a positive feedback results.

V. Conclusion & Future Work

A variety of data on the internet is being created every minute of every day; it is difficult to find important and necessary information from tremendous amount of data. In this research, our main goal is to let users able to track the time-varying data changes by audio and visual hint. Through playing the harmonic chord while the focused data structure has changed, this approach is capable of attracting users' attention immediately. In addition, according to the force-driven approach and color mapping, the keyword clusters will adjust the distance between each cluster to display relationship.

In the current experimental results, the patterns we found are still not prominent enough. We think one of the reason is because the volume of data we used for experiment is not big enough for us to find highly similar patterns. In addition, for our experiment, it is also necessary to adopt and investigate more methodologies used to establish the relationship of data. Furthermore, as one of the future works, we are adding filter functions to our system. These filter functions aim to help users for extracting and manipulating meaningful patterns in a more intuitive and user-friendly manner.

Acknowledgments and Legal Responsibility

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Questionnaire

Statement	Strongly agree	Agree	Neither Agree or Disagree	Disagree	Strongly Disagree
1. Do the connections between keyword clusters meet your expectation?					
2. Can you figure out which keyword clusters are more connected?					
3. Are you impressed with the relationship between keyword clusters?					
4. Comparing with exam 1，do the connections between keyword clusters meet your expectation?					
5. Comparing with exam 1，can you figure out which keyword clusters are more connected?					
6. Comparing with exam 1，are you impressed with the relationship between keyword clusters?					
7. Comparing with exam 2，do the connections between keyword clusters meet your expectation?					
8. Comparing with exam 2，an you figure out which keyword clusters are more connected?					
9. Comparing with exam 2，Are you impressed with the relationship between keyword clusters?					
10. Comparing with previous exams, do the relationship between keywords clusters after refreshing page meet your expectation better?					

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