Baguamarsh: An Immersive Narrative Visualization for Conveying Subjective Experience

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Abstract. As ubiquitous sensing becomes embedded in our everyday world, we can easily obtain multimodal sensor data from our physical surroundings. Objectivity is a core value in the visualization research community. However, personal experiences are characterized not only by objective facts, but by personal emotions. In this paper, we explore immersive data visualization for conveying personal subjective perception and experience by using multidimensional data and multimedia. We introduce a framework to describe narrative structures in immersive data visualization, and provide an example project Baguamarsh as a proof of theme-based creative methods for designing correlations between different information. We hope this study may offer outline opportunities for future research in narrative visualization.

Keywords: Virtual reality · Narrative visualization · Multidimentional data · Storytelling · Bagua · Book of Changes

1 Introduction

As ubiquitous sensing becomes embedded in our everyday world, we can easily obtain multimodal sensor data from our physical world, as personal health data, meteorological data, geographical data and etc. There are many approaches that have been designed to present date for users to communicate information clearly and efficiently. Data visualizations are commonly presented quantitatively, as statistical graphics, plots, charts and other tools [1]. Objectivity is a core value in the visualization research community [2]. However, personal experiences are characterized not only by objective facts, but by personal emotions [3]. How to convey personal subjective perception and experience by using multidimensional data becomes both an opportunity and a challenge in visualization field.

On the one hand, storytelling is an effective way of conveying information and enhancing understanding [4], as narrators can leverage personal information (data, photos, audio, etc.) and express their subjective ideas through narrative visualization. On the other hand, as VR headsets have become affordable for individuals, virtual reality becomes a user-friendly platform for reconstructing and representing digital information.

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In this paper, our approach treats the data visualization as a narrative and uses virtual reality as a platform to convey a narrator's story. Firstly, we discuss related work on visualization research. Secondly, we introduce a framework to describe narrative structures in immersive data visualization. Finally, we provide an example project "Baguamarsh" as a proof of concept. Each of these aspects plays a great role in allowing the narrator to affect the observer emotionally and intellectually by conveying a rich, significant idea.

2 Related Work

2.1 Pre-research

Project "Moments" is a prototype system for saving and representing personal moments [5] and presents an overview of a whole process of creating an immersive data visualization, which provide a good reference value for this study.

A wireless sensor network (deployed at Tidmarsh Wildlife Sanctuary in southeastern Massachusetts) [6], and Chain-API (a RESTful service providing sensor data), provide a place instrumented with a dense senor network for field study and an open-data platform for collecting environmental data, hence provides an ideal setting for this project.

2.2 Subjectivity in Narrative Visualization

As narrative visualizations combine patterns of communicative and exploratory information visualization to convey intended stories [4], many communities have commented on the importance of narrative in data visualization [9]. But according to Tong et al. [7], comparing with the development in other fields, storytelling is a relatively new subject in visualization. On one hand, even storytelling has become a common topic of discussion in data visualization now, but most research commonly represents objective facts [7], and there is only a little research on personal storytelling [3]. On the other hand, there are some data artworks that express subjectivity as a design goal, but they do not describe specific techniques and methodologies for creating subjective representation [3].

2.3 Immersive Data Visualization

Virtual reality not only has been shown to lead to better discovery in domains whose primary dimensions are spatial [8], but also to enhance situation awareness [9] and media richness [10]. On one hand, according to Donalek et al., as virtual reality can maximize the intrinsic human pattern recognition skills [8], immersive data visualization provides more intuitive data understanding than traditional "desktop" visualization tools. On the other hand, the public has understood that virtual reality already portended a new medium for almost two decades [11], and we have seen much research on interactive experience, presence, immersion and interaction [12–17], but not many works that address immersive narrative visualization involve live sensor data.

3 Framework

We explore the use of immersive virtual reality platforms for narrative visualization to convey subjective experience. To achieve our goal, we introduce a theme-based framework (shown in Fig. 1) with which a user not only can convey personal subjective perception and experience by using multimedia and multidimensional data, but also can enhance multidimensional expression.

According to the commonly used pipeline for collecting data [3] and creating information visualizations [18], we inject a theme-based method in workflow to represent subjective personal narratives in an immersive environment. Firstly, a main theme chosen by a narrator is the selection criteria for collecting information (data, media, etc.). Secondly, according to the theme, the narrator can choose to simplify, classify, connect or reconstruct information materials. Thirdly, rhetorical strategy is used to map all content for representing annotation, user interface, presence and interactivity. Finally, perceptualization is integrated for building up an immersive and interactive environment.

4 Project Introduction

In this section, we present a project "Baguamarsh" that exemplifies the goals described in last section. This project takes the idea of the unity between heaven and man of the ancient Chinese philosophy I Ching (Book of Changes) [19], combines the Bagua (Eight Trigrams) of the I Ching with multidimensional data and multimedia, and uses an immersive interactive environment to present a novel form of narrative visualization. The main theme of this project is the "Unity between Heaven and Man", namely the harmony of nature and human. It systematically expounds the relationship between man and nature, that man must follow the laws of the universe, to respect and protect nature, and to have an insight into the truth that harmony can produce all things. According to the main theme, we designed this project under the form of a virtual reality environment by integrating personal data, environmental data and media materials.

An I Ching framework has been used in prior work to interpret and represent wearable sensor data for a quantified self application [20], but not to our knowledge for integrated personal and large-scale environments sensing.

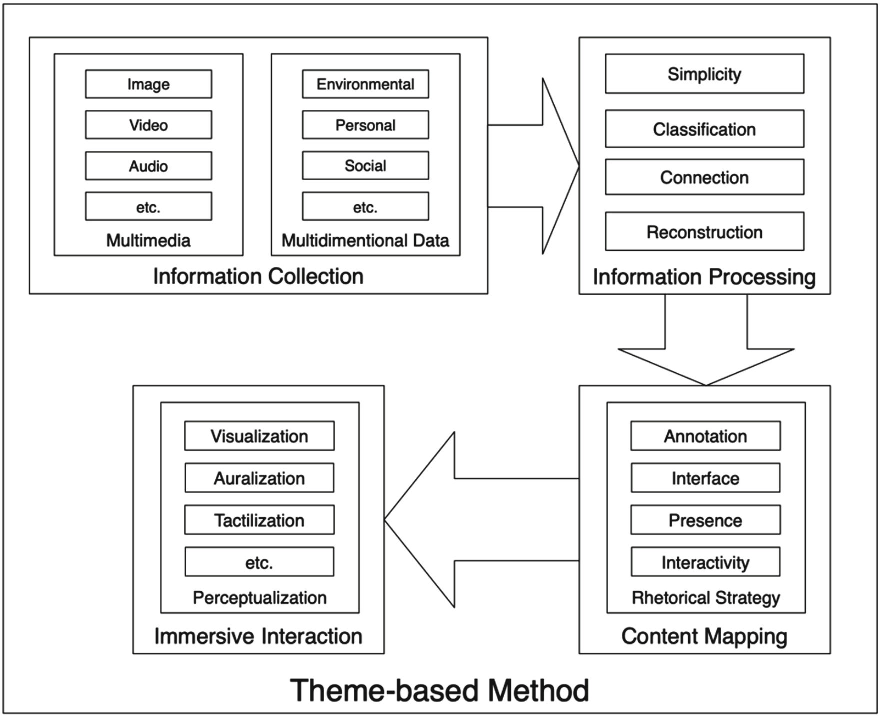

Fig. 1. Theme-based framework for constructing immersive narrative visualization

5 Information Collection and Processing

The data used for this project is divided into user data and environmental data. The user data is mainly from wearable devices, that is to say an Apple Watch 4 and a Muse BioHarness in this project. These two kinds of devices are separately responsible for collecting a narrator's ECG and EEG. Environmental data is mainly obtained in two ways: (1) a GoPro 360 camera is responsible for taking 360° panoramic photos and recording ambisonic audio from user environments (shown in Fig. 2), (2) Using the open data interface to obtain environmental data through time and GPS information encoded in the panoramic photo EXIF information.

Fig. 2. Devices for information collecting

After the narrator wearing the wearable devices enters the data collection area (Tidmarsh), he/she firstly takes a panoramic photo with the 360 camera, and then starts recording a panoramic video of about 30 s in the same position (the video contains ambisonic audio) (shown in Fig. 3). During the video recording process, he/she needs to collect ECG and EEG data for about 30 s when the mobile phone is connected with the wearable device. The narrator may take advantage of the features of the 360° camera, as he/she doesn't need to focus or frame when shooting image material, so he/she can collect other data at the same time, which greatly shortens the information collection time. After actual operation, we find that the information collection process for one location usually takes no more than 2 min.

Fig. 3. Information collection in Tidmarsh

Information processing is mainly divided into three steps: information extraction, data expansion and data archiving (shown in Fig. 4). (1) Information extraction: mainly for the image materials captured by the 360° camera, which includes panoramic photos and panoramic videos. The panorama photo is a JPG image file, and each file contains EXIF information. We use a program written in Python to extract the time and GPS information from each photo for later use in data expansion. The extraction process for panoramic video file information is relatively time consuming. We import the panoramic video into the post-processing software Premiere before extracting the 4-channel ambisonic audio. In addition, we use a sound generation program written in Python to convert the ECG signals collected in the previous period (Fig. 4, top) into 30-s heartbeat sounds, which will be used in the later virtual reality interaction. (2) Data expansion: using the time and GPS information in the previous photos, we obtain the 24-h environmental information of the information collection day through an open data interface. The open data platforms used in this project include the following: Google Maps API, AccuWeather APIs, Chain API [21]. We use Python-written programs to get locations and elevations from the Google Map API, get temperatures and winds across the entire area from AccuWeather APIs, and get the pressure, relative humidity, visible light, intensity of infrared and ultraviolet light, soil temperature and humidity from the Chain API in the area where the user is located at Tidmarsh. We put all of this data together to generate a text file in JSON format. (3) Data archiving: We use the desktop program written by Unity to package panoramic photos, ambisonic audio and text files containing all metadata into an archive file, which is convenient for subsequent virtual reality program calls.

6 Content Mapping

The way we present content has the following characteristics: (1) Narrative visualization will be presented in the VR environment reconstructed from 360 panoramic photos, and users can switch between the real environment and special effects environment. (2) By combining the physical properties of the phenomena described by the data with commonly used visualization methods, we develop novel and user-friendly modes of presentation. (3) Eight Trigrams (see below) will persist across the entire visual representation, and the symbols corresponding to each kind of trigram will be adopted as the basic visual elements of the environmental data points, which also reflect the connection between data and trigrams on the micro level and make the observation more convenient, thereby improving annotation. (4) Most of the visualization objects in this project are time series datasets in the unit of scenes. All data points can not only display the visualization effects at different times and in different trigrams, but also reflect the relationship between personal data and environmental data, thereby abstracting a visual pattern of “Unity between Heaven and Man” to users.

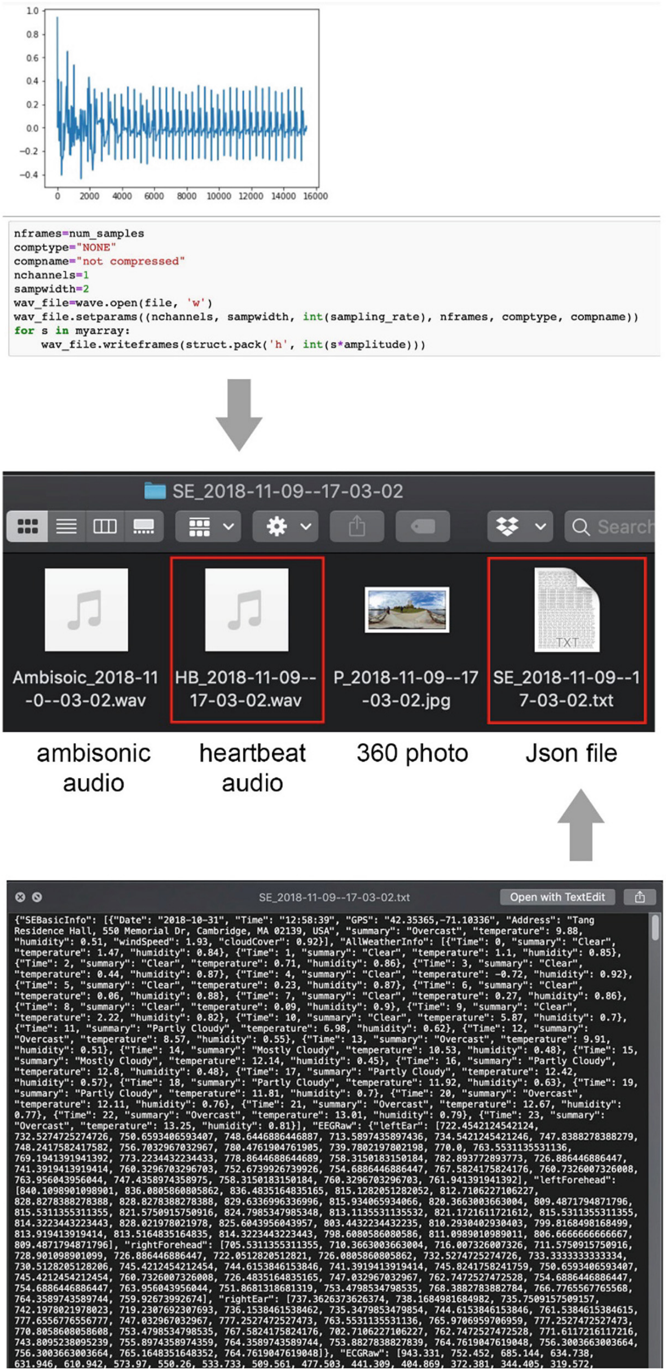

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Fig. 4. Information processing

Eight Trigrams are the basic concept of the Book of Changes and can represent the dynamic and still states of all natural phenomena. Eight kinds of symbols used in the Eight Trigram correspond to eight phenomena in nature (Heaven, Earth, Water, Fire, Thunder, Wind, Mountain, Marsh), and their names are “Qian, Kun, Kan, Li, Zhen, Xun, Gen and Dui”. Through the evolution of these eight natural phenomena, we speculate on the laws of man and nature in an attempt to achieve a world view of harmony between humanity and nature. The Eight Trigrams are divided into Earlier Eight Trigrams and Later Eight Trigrams. What is used in the project is the Later Eight Trigrams, which are said to have been made by Zhou Wenwang. In the Later Eight Trigrams, the Trigram Zhen is the starting point and it is due east. According to the clockwise direction order, there are in sequence: Trigram Xun–Southeast; Trigram Li—South; Trigram Kun–Southwest; Trigram Dui—West; Trigram Qian–Northwest; Trigram Kan—North; Trigram Gen–Northeast. The order of the Later Eight Trigrams are: one of Kan, two of Kun, three of Zhen, four of Xun, five of the center, six of Qian, seven of Dui, eight of Gen, and nine of Li. The ancients used to draw maps with south at the top and east in the left. We create a three-dimensional interactive menu based on graphics of Eight Trigrams and the shape of the Fengshui Bagua mirror for the interaction of the VR controller (shown in Fig. 5).

Fig. 5. Bagua menu

According to the eight phenomena described in the Bagua, we divide the acquired environmental data into eight categories that correspond to each of the Trigrams (shown in Fig. 14) in the menu: (1) Trigram Qian: atmospheric pressure (2) Trigram Dui: soil moisture (3) Trigram Li: UV index (4) Trigram Zhen: cloud cover (5) Trigram Xun: wind speed (6) Trigram Kan: humidity (7) Trigram Gen: elevation (8) Trigram Kun: soil temperature. Users can interact with the data space through the Bagua menu: the specific visualizations are as follows (Figs. 6, 7, 8, 9, 10, 11, 12 and 13):

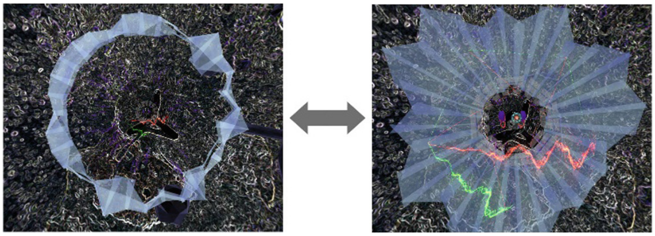

Fig. 6. Trigram Qian – atmospheric pressure (AP): the atmospheric pressure data is used to control the volume of a ring around an object. The higher the pressure, the larger its volume.

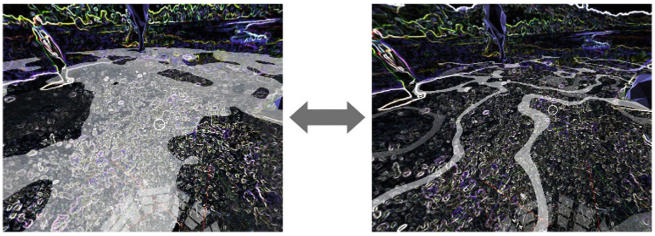

Fig. 7. Trigram Dui – soil moisture (SM): the soil moisture data is used to simulate the water on the ground. The greater the moisture value, the wider the line of water.

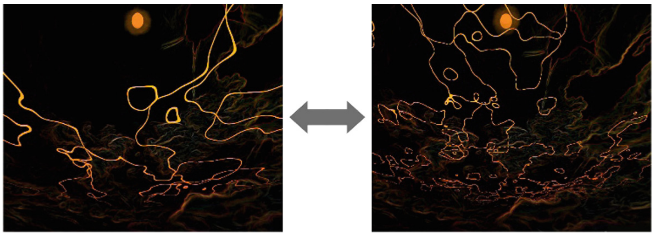

Fig. 8. Trigram Li – UV index (UV): the UV index represents twinkling lines in the sky. The higher the value, the high their density.

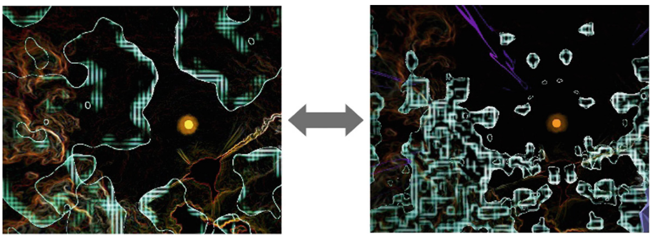

Fig. 9. Trigram Zhen – cloud cover (CC): the value of cloud cover is used to control the density of clouds in the sky. Cloud density increases with the value of cloud cover.

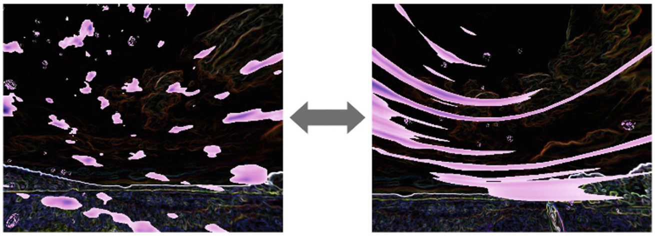

Fig. 10. Trigram Xun – wind speed (WS): wind data is used to control the rotational speed of visual elements. The higher its value, the faster the rotational speed.

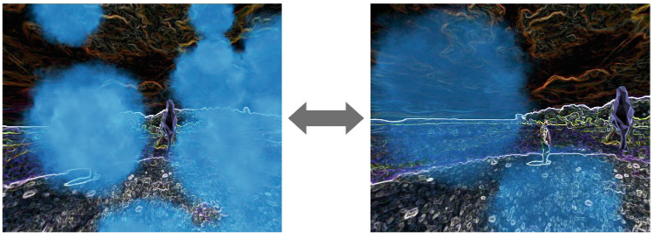

Fig. 11. Trigram Kan – humidity (Hu): humidity is used to control the density of visual elements. The larger the value, the higher the density.

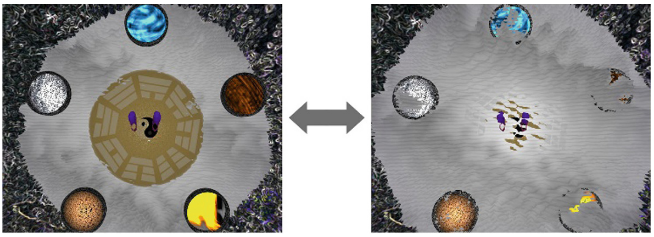

Fig. 12. Trigram Gen – elevation (El): elevation data controls height differences between water particles and other objects. The higher the value, the bigger the gap.

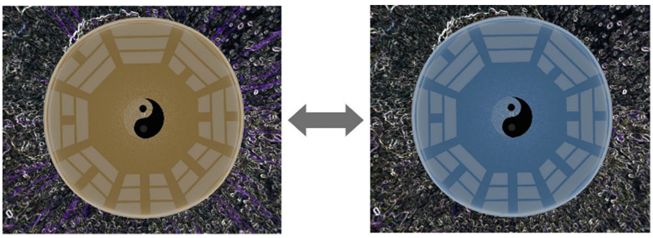

Fig. 13. Trigram Kun – soil temperature (ST): the soil temperature is used to control the color tone of ground material. The higher the temperature, the warmer the color.

According to the I Ching, Trigram Qian corresponds to the body's brain, and Trigram Li corresponds to the heart. We build the EEG and ECG into a dynamic model, then place them at the centre of the interactive menu. Both the EEG and ECG data are displayed as line graphs around the model, and all environment data is shown on the submenus attached to the interactive menu (shown in Fig. 5).

The green main menu can be rotated by the VR controller. Each Trigram contains different kinds of data and different combinations of the Five Elements which are designed for triggering visual effects.

Users can select the environmental data within 24 h of the day of the encounter through the menu selection. We map the elements represented by each trigram to the relationship between the five elements. We superimpose the elements corresponding to these attributes over the visual elements manifested by different data to reflect the process of mutual promotion and restraint between the five elements (shown in Fig. 15 and Fig. 16), reflected by the Eight Trigrams. The calculation formulas for each Trigram are as follows:

$$\text{Qian: } f(AP) = AP + EEG + El - UV \tag{1}$$

$$\text{Dui: } f(SM) = SM + ST - UV \tag{2}$$

$$\text{Li: } f(UV) = UV + ECG + CC + WS - Hu \tag{3}$$

$$\text{Zhen: } f(CC) = CC + Hu - SM \tag{4}$$

$$\text{Xun: } f(WS) = WS + Hu - AP \tag{5}$$

$$\text{Kan: } f(Hu) = Hu + AP + SM - ST - El \tag{6}$$

$$\text{Gen: } f(El) = El + UV - CC \tag{7}$$

$$\text{Kun: } f(ST) = ST + UV - WS \tag{8}$$

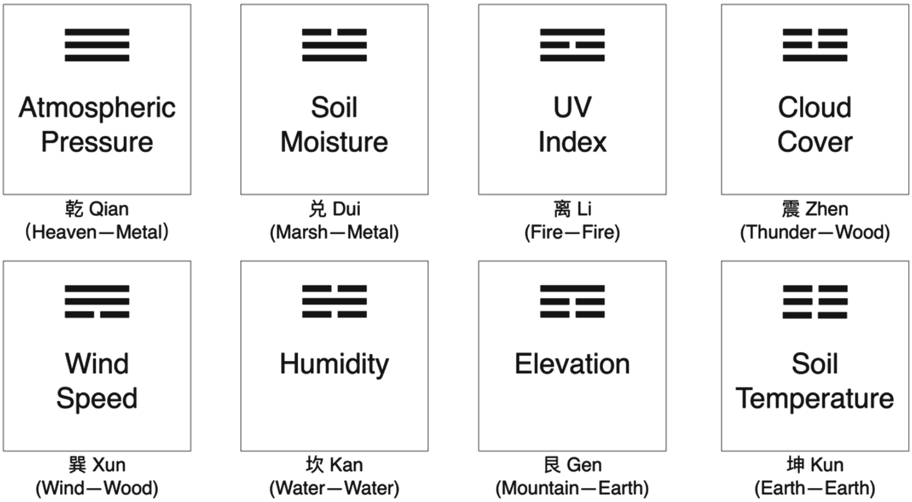

Fig. 14. Data mapping of eight Trigrams

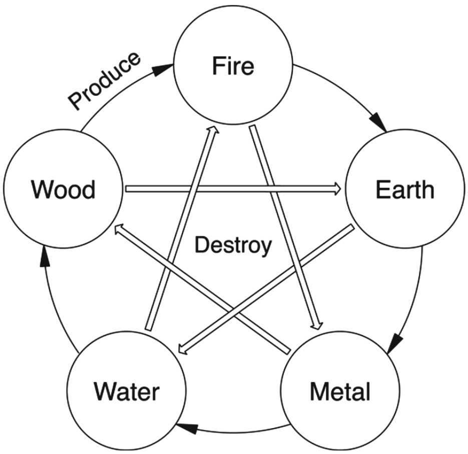

Fig. 15. The production and destruction relations in five elements

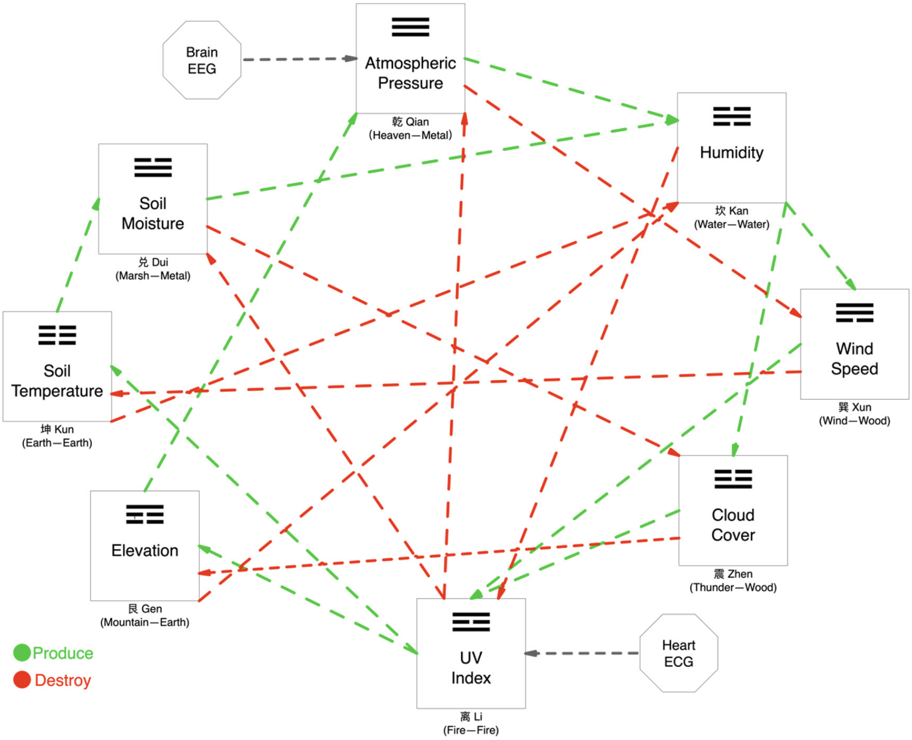

Fig. 16. The algorithm of relations for data interaction

Before we use the algorithm, there are very little differences between each time point, so users can hardly feel the interaction in VR. By using the calculation formulas of the mutual promotion and restraint between different data, the visual effect changes dramatically, which can provide the user a better interactive experience. When a user chooses a different Trigram, the lines between each element will be changed. The green line represents production and the red line represents destruction (shown in Fig. 16).

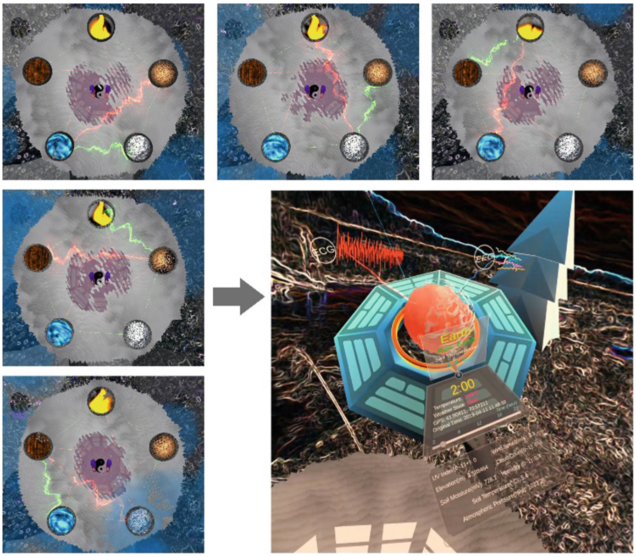

Fig. 17. Different options presents different hints (Color figure online)

7 Immersive Interaction

For highly immersive visualization purposes, a first-person view is appropriate (shown in Fig. 18). The observer will experience both visual and audio cues. This project is currently available as a prototype application for Oculus Go, which has a relatively high performance/price ratio on the market. This VR headset does not need to be connected to a computer, which makes a better user experience. In terms of software production, we use Unity3D to import the archive files that were previously packaged by the desktop program into the VR main program in batches, and generate an Android program that supports Oculus Go. Based on the characteristics of the device, we design a VR interactive mode according to the mode chosen in the menu.

When a user is in the VR environment, he/she can not only walk around, look around, hear 3D background sound, select scenes, and hide or move visual objects, but also can select different trigrams to explore different visualization and auralization results. For example, when a user chooses Trigram Li, it will begin to rain Trigrams (shown in Fig. 19). He/she can hear the sound of heartbeats and a UV Index data value is loaded for the interactive menu. The users can switch between the real environment and the data environment (shown in Fig. 21), or change the time to see what would happen to the environment then. He/she can even use the controller cursor to select a 3D object to change its appearance (shown in Fig. 20) based on the value of Trigram that he/she chose.

Fig. 18. First-person view

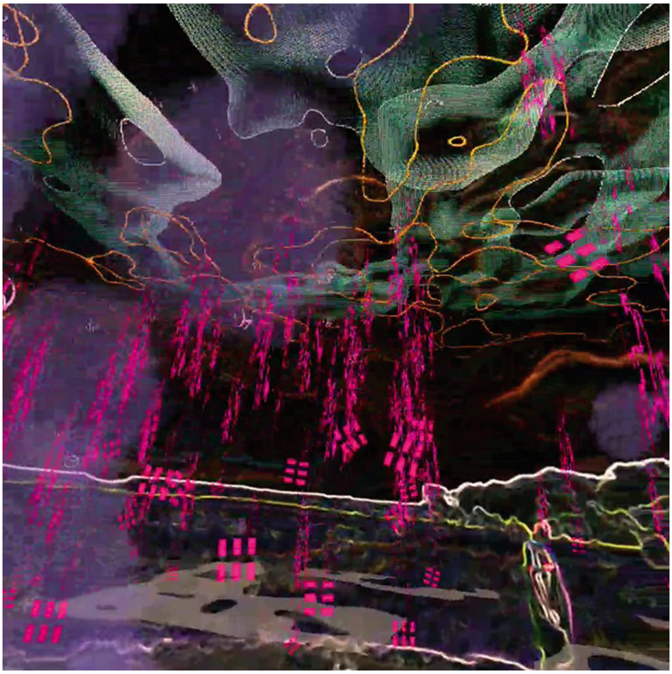

Fig. 19. Trigram rain for notification

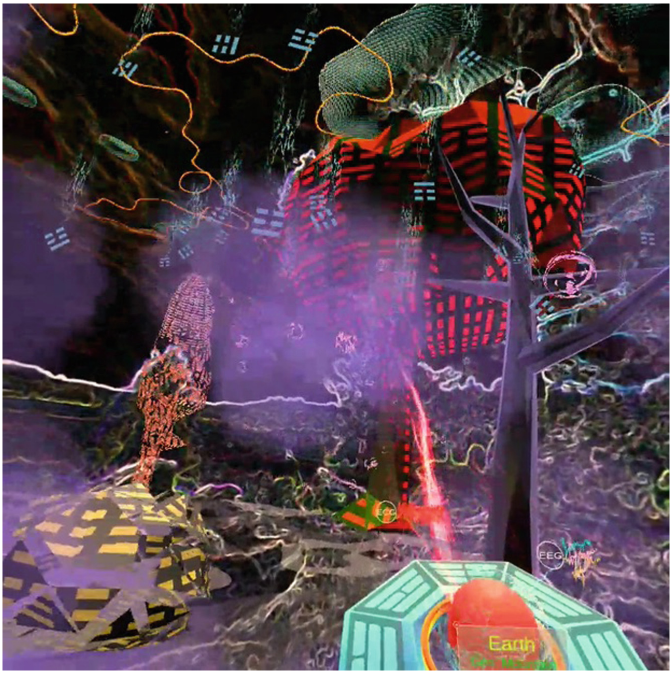

Fig. 20. Change the appearance of a tree

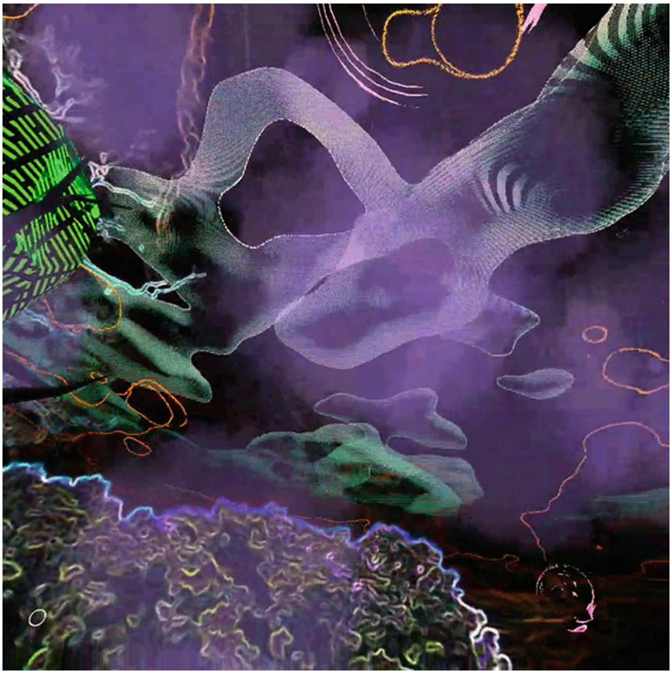

Fig. 21. Sky of data environment

8 Conclusion

In this paper, we introduced a framework and an ongoing project to describe how to design an immersive narrative visualization for conveying subjective experience. We describe the whole process of project Baguamarsh for deliberately expressing subjectivity during information collection, processing, interaction and presentation. These preliminary studies show us the first insights into the potential of immersive data visualization as a subjective storytelling platform and prompt a discussion for future research on conveying subjective experience in personal visual storytelling. More visuals and video from this project can be viewed at https://www.media.mit.edu/projects/baguamarsh/overview/.

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