Multi-Modal 3D Geographical Information Systems with Haptic Interface

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Abstract. The objective of the research reported here is to develop a Multi-modal 3D Geographical Information Systems (GIS) with haptic interface. In 3D environments, the complex spatial relationship between the entities and the influence of the light and shadow make operations of objects difficult and inefficient. Haptic interaction is then considered as an effective auxiliary method. We studied the feasibility of multi-modal 3D GIS with haptic interaction and then conducted the experiments of applying the haptic display into bivariate thematic 3D maps to get evaluations of haptic interaction quantitatively. The main results of the study indicate that adding haptic interaction into GIS can improve the performance of the 3D GIS apparently. The results of this work could be used as a foundation for future study on developing more sophisticated GIS with haptic interface.

1 Introduction

In the 3D environments, the spatial relationships of objects in GIS become more complex than in the traditional 2D display. Furthermore, the interference for color reorganization caused by the light and shadow cannot be neglected. Our eyes will make more mistakes in 3D environments and the operations only by vision will be difficult and inefficient. In addition, it is not easy to move and operate in 3D display by traditional 2D devices such as mouse and keyboard. To resolve these problems we added the haptic interface into the GIS systems. Haptic interaction is one of the most fundamental ways in which people perceive and effect changes in the world around them [1]. It is believed that adding haptic interaction into the 3D GIS is useful for getting and understanding the spatial information more quickly and correctly. Furthermore, Some haptic devices provide operation in 3D space with 6 degree of freedom (such as the PHANToM Desktop device used in our research). In addition, for the people with visual impairments, haptic interaction is helpful for them to understand the spatial information instead of vision.

Some work has been done in representing geographical data by haptic display. Haptic displays such as 3D Grid force and viscosity-like force have been used to help geoscientists in oil companies operate and interpret seismic data [2]. Jeong *et al* [3] has also reported that adding haptic display could improve the performance of users of 2D bivariate thematic map. In our research, we constructed a 3D bivariate thematic map and compared the performance of visual display with haptic display (vibration and viscosity-like force). The quantitative evaluations of haptic interaction in 3D GIS are made by the experiments and the results could be useful to researchers studying both haptic interaction and GIS.

2 3D Bivariate thematic map

Bivariate thematic map is the map that has two different themes represented by two different color schemes. The common map has only one theme, such as a weather map representing temperature distribution. We can use one map to represent two themes by increase more color them. For example, if one theme has three values, we will get 9 different combinations of values. Then we can use 9 different colors to represent them in one map. Apparently, this kind of bivariate thematic map is extremely difficult to understand because it is not easy to remember the meaning of so many colors. The user need refer to the legend all the time. However, if one theme is represented by color and the other theme is represented by haptic display, it may be easier to understand because user can rely not only on visual cues but also on tactile feedback. . In this research, we use vibration and viscosity like force as the haptic display. For the requirement of free operation in 3D environments, we choose the PHANToM Desktop device. The PHANToM desktop is a desktop tool that allows for the exploration of application areas requiring force feedback in six degrees of freedom (6DOF) [4]. User can query property of every sub space in the 3D map by the stylus grip of PHANToM in the virtual 3D environment freely.

3 Experiments

We construct a simple 3D bivariate thematic map by OpenGL to compare the performance of visual display with haptic display (see Figure 1). To simplify the process of creating 3D space, 27 adjacent cubes are used to compose a 3D space, in which every cube represents a sub-space with its own property. In the map there are two themes: temperature and humidity, each has 3 values: High, Middle and Low. The map has a legend to provide user the color reference. When cursor are moved into a cube, the color of the cube is display, and the vibration or viscosity like force can be felt by PHANToM, if there is haptic display. In the experiment involving haptic interaction, the different colors are used to represent the temperature while the haptic display (vibration and viscosity-like force) represents humidity. Strong vibration or viscosity represents high humidity while small vibration or viscosity represents low

humidity. In contrast, in the experiment without haptic interaction, the nine different random colors are used to represent 9 combinations of variables.

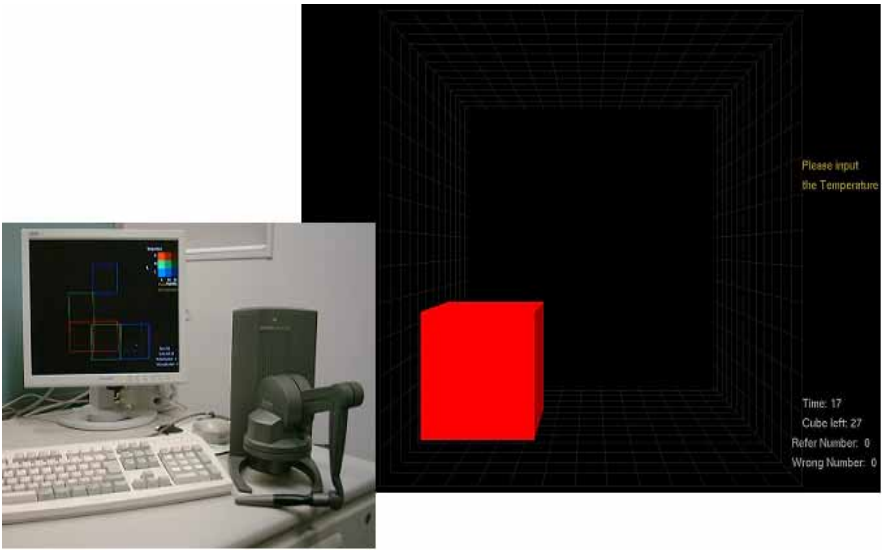

Figure 1: Experimental Environments

We recruited a dozen of participants to test the haptic interaction in the experiments. They were asked to tell the properties, that is, temperature and humidity of all 27 cubes in the map. The participants can refer to the legend if they forget the colors' representations. The participants were asked to do a learning phase before the main experiment to get accustomed with the system The 3D map used in both learning phase and main experiment is the same, except the color solution is changed every time randomly. Every participant was asked to do three experiments: Only-Color, Color-Vibration and Color-Viscosity. The evaluation will be made by four measurements:

- Completion time
- Forgetting rate (frequency of reference to legend)
- Mistake rate
- Subjective satisfaction (Mean Opinion Score).

After experiment, the participants will evaluate the color-haptic modes by choose the satisfaction level from 1(worst) to 5 (best).

4 Result and Conclusion

The results of the experiments are showed in Table 1. It can be seen that adding haptic display can reduce the completion time and forgetting rate and mistake rate of users significantly. From the results of ANOVA analysis of completion time showed in Table 2 it can be seen that the mean difference is significant between no-haptic

display and haptic display, but the mean difference between vibration and viscosity is not significant, although the recognition of vibration is considered much easier than that of viscosity. Jeong's experiments showed that haptic displays seem to interfere with other modalities because color is very powerful in 2D map[3]. However, our results show that adding haptic can improve the performance of GIS including average completion time because it seems difficult to judge colors in 3D environments with the influence of light and shadow.

	Only-Color	Color-Vibration	Color-Viscosity
Completion Time(s)	179	93	111
Forgetting Rate	6	0	0.08
Mistake Rate	11.6	3.2	4.4
MOS	1.5	4.7	3.75

Table 1 Average Evaluations of Three Modes

	Source of Variation	SS	df	MS	F	P-value	F crit
Only-Color VS. Color-Vibration	Between Groups	44462.04	1	44462.04	61.78176335	7.9E-08	4.300944
	Within Groups	15832.58	22	719.6629			
	Total	60294.63	23				
Only-Color VS. Color-Viscosity	Between Groups	27880.17	1	27880.17	27.05897	3.24E-05	4.300944
	Within Groups	22667.67	22	1030.348			
	Total	50547.83	23				
Color-Vibration VS. Color-Viscosity	Between Groups	1926.042	1	1926.042	3.846168	0.062639	4.300944
	Within Groups	11016.92	22	500.7689			
	Total	12942.96	23				

Table 2 ANOVA Table for Completion Time (0.05 level)

The results indicate that by using 3D haptic device, we can not only query the entities in the 3D GIS directly but also improve the whole performance of the system apparently. Encouraged by the results of this study, we will continue to construct more sophisticated 3D GIS with haptic display in the future.

References

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