

Development of Virtual Geographic Environments and Geography Research

Fengru Huang¹, Hui Lin¹, and Bin Chen²

¹ Institute of Space and Earth Information Science, Chinese University of Hong Kong, Shatin, N.T., Hong Kong

² Institute of Remote Sensing and Geographic Information System, Peking University, Beijing, China

{huangfengru, huilin}@cuhk.edu.hk, gischen@pku.edu.cn

Abstract. Geographic environment is a combination of natural and cultural environments under which humans survive. Virtual Geographic Environment (VGE) is a new multi-disciplinary initiative that links geosciences, geographic information sciences and information technologies. A VGE is a virtual representation of the natural world that enables a person to explore and interact with vast amounts of natural and cultural information on the physical and cultural environment in cyberspace. Virtual Geography and Experimental Geography are the two closest fields that associate with the development of VGE from the perspective of geography. This paper discusses the background of VGE, introduces its research progress, and addresses key issues of VGE research and the significance for geography research from Experimental Geography and Virtual Geography. VGE can be an extended research object for the research of Virtual Geography and enrich the contents of future geography, while VGE can also be an extended research method for Experimental Geography that geographers can operate virtual geographic experiments based on VGE platforms.

Keywords: Virtual Environment, Virtual Geography, Experimental Geography, Virtual Geographic Experiment.

1 Introduction

Geographic environment is a combination of natural and cultural environments under which humans survive, and traditional geography takes geographic environments in the real world as its study object. Geography aims to study the physical, chemical, biological and human processes of the geographic environment (the earth surface system), analyze the relationships between the interfaces of each geo-spheres, and interaction mechanisms between various natural and human processes, thus to explore the precepts of coordinative and sustainable development of resources, environments and human activities.

As the development of information technologies such as Internet, Web and Virtual Reality goes further, both new opportunities and challenges are generated for the development of geographic information sciences and technologies, as well as for geography sciences. Virtual Geographic Environment (VGE) was first proposed in

early 2000 by geography and geographic information science researchers [1, 2, 3, 4]. VGE is a new multi-disciplinary initiative that links geosciences, geographic information sciences and information technologies. A VGE is a virtual representation of the natural world that enables a person to explore and interact with vast amounts of natural and cultural information on the physical and cultural environment, in cyberspace. From the perspective of geography, VGE is an environment concerned with the relationship between avatar-based humans and 3-dimension (3D) virtual worlds. From the perspective of information systems, VGE is an advanced information system that combines GIS (Geographic Information System) with VR technology [1, 2, 3]. At present, there has launched much research into VGE theory, technology and applications [5, 6, 7, 8]. Those works focus on different aspects of VGE research and thus raise broader and more complicated research such as topics on geo-data, geo-models, geosciences knowledge acquisition, GeoComputation, geo-visualization, geo-collaboration, interaction mode, virtual geographic experiments and Virtual Geography. To address this, this paper aims to discuss the background of VGE, introduce its research progress, and address key issues on VGE research and the significance for geography research from the perspectives of Experimental Geography and Virtual Geography.

This paper is organized as follows. In section 2, we discuss background and research progress of VGE, as well as its research contents and key issues. In section 3, we present revolution of geography research method and geographic language. Section 4 and Section 5 discuss development of Virtual Geography and development of Experimental Geography, respectively. Section 6 contains some final discussion and remarks on VGE and geography research.

2 Background and Research Progress of VGE

2.1 What Is VGE?

VGE was first proposed as a concept of a virtual world that was referenced to the real world, which had five types of space, namely Internet space, data space, 3D graphical space, personal perceptual and cognitive space, and social space [2]. To this concept regard, there are three stages in the evolutionary process of a VGE: virtual crowds, virtual villages and virtual cities. In this sense, VGE research focuses on the differences and extension of life content and life style from the real world to virtual worlds, or between the real world and a virtual world, and thus relate to research of Virtual Geography or other terms alike. To make emphasis on representation of geographic process and phenomena in the real world, such as visualization and simulation of geomodals in diverse geosciences, the concept of VGE has been supplemented as a new generation of information platform that can be used for geo-phenomena representation and simulation, and geo-knowledge publishing and sharing [9]. Such a VGE represents an ideal interface of geo-information scientists for geographic representation and research, that is ‘immersive experience and beyond the understanding of reality’. VGE systems have five characteristics:

- 1, Integrated management and interoperation on geo-models and GIS data;
- 2, Multi-dimension geo-visualization, including visualization of geometric models (represent static objects) and geo-models (represent dynamic geographic processes);
- 3, Immersive virtual interaction: users can 'step' into the virtual geographic world and be a part of the environment, thus have an immersive interaction with the virtual environment.
- 4, Distributed geo-collaboration: geographic experts from different places/locations of the real world can carry out professional discussion and decision-making with the support of VGE platform;
- 5, Public participation: VGE emphasizes on the role of social public participation, so the users are not just experts and professional users, but also the general public.

2.2 Why VGE Rising?

The rising of VGE has a profound background that includes not only development of geographic sciences, but also currently rapid development of computer technology, information technology and social sciences. The development of VGE is closely related to the development of Earth System Science and will ultimately serve the research of global environment change and human sustainable development.

1, Earth System Science research needs a new research tool and information platform in which scientific computation and virtual representation are the two important characteristics, to facilitate simulation and prediction on natural complex phenomena that can not be experimented in the real world conditions, such as prediction on the whole cycle of the Earth's atmosphere-ocean, global warming, Earth's crust change, earthquake occurrence, and human behavior simulation in emergency public accident or natural disasters, so as to help manage on environmental resources and human activities to achieve sustainable development.

2, Current rapid development of Earth information technologies provides technical support for the emergence of VGE. As the development of mathematical scientific methods (for example, scientific computation, cellular automation, fractal geometry, fuzzy mathematics, etc), and computer science and technologies (such as computer communication, networks, databases, distributed computing, artificial intelligence, human-computer interaction and virtual reality) goes further and is being applied to geographic science and Earth System Science, there has been continuous development from different angles in the field of Earth information technologies. This provides support for the rising and development of VGE, which integrates with Remote Sensing (RS), Global Position System (GPS), Geographic Information System (GIS), computer network, virtual reality technology, and other computer technologies.

3, The field of social and cultural sciences require a research platform or a window like VGE to learn about human development trends in the age of post-modernism. The style of post-modern society has the basic characteristics as "information age", "knowledge economy" and "learning society", and has actually penetrated into various aspects of contemporary human society, quickly and fully. In recent years, geography research activities and literature have been increasing with regard to the impact of modern information technology on geography. For example, Batty [10, 8] proposed "invisible cities", "Cyberspace Geography" and "Virtual Geography" in terms of geographic space-place, espace, cyberspace, and cyberplace. Increasing public is being

familiar with and a part of virtual environments, virtual earth, or virtual worlds. The new styles of learning, working and living, such as e-tourism, e-education, e-shopping, virtual communities, virtual office, virtual banking, virtual stock market, virtual games, and virtual art appear in succession and show a strong vitality, and may represent human development trends and directions in the post-modern age. Therefore, from the perspective of social scientists who study socio-economic, political, legal, cultural, and human psychology, behavior and life styles of the post-modern age, something like VGE as a research window is needed to help to explore characteristics and development trends of human society of the post-modern age.

2.3 Related Work

VGE is developed with the support of the advancement in computer science and technologies, geosciences, Geographic Information science and techniques. Only by combination of those theories and technologies to construct an integrated platform can we meet the need of the development of Earth System Science for global environmental change and sustainable development research. In recent years, much progress has been made on such a next-generation geographic information platform from different aspects. Chinese scholars have been engaging actively in relevant research since VGE was put forward a decade ago. Lin and Gong explored basic theory, technology and application of VGE through a series of academic work and papers [1, 2, 3, 4, 9, 11]. Tang et al. studied on visual geographic modeling and construction of VGE [12].

Researchers in the Electronic Visualization Laboratory (EVL) of The University of Illinois have focused on the development of tools, techniques and hardware to support real-time and highly interactive visualization [13], and the platform GeoWall [14] was developed with the characteristics of users' immersive interaction with the virtual environment which was displayed to the big screen. MacEachren developed a system named Dialogue Assisted Visual Environment for Geoinformation (DAVE_G), in which the earlier multi-modal interface framework and two test-bed implementations: iMap and XISM [15] were built on and extended. Batty, M. established virtual city and explored Virtual Geography [8, 10, 16]. Yano built Virtual Kyoto through 4D-GIS and Virtual Reality to show social customs and traditional culture in Japan [17].

Google, Microsoft, Linden Lab and other companies started to build community, city, region, or even global 3D virtual environments. Google developed Google Earth for public searching the high resolution digital map freely [18], and Google SketchUp [19] for 3D models building. Microsoft launched Virtual Earth project, which was built up by using photos and offered a higher sense of reality [20]. Linden Lab created and opened Second Life® to the public since 2003, and now it owns the largest amount of virtual residents and many kinds of applications such as virtual meeting, virtual class, virtual industry, etc., in its virtual world [21]. As one of the approaches of VGE application construction, some GIS-based multi-user virtual environment applications are being carrying out based on virtual world platforms such as Second Life®, OpenSimulator [22] or other similar projects. We can therefore see that, as a new generation of geographic information platform, VGE development has a broad prospect for geography research.

2.4 Research Contents and Key Issues of VGE

In contrast to current data-centered GIS, a VGE is a human-centered environment. A VGE system can present immersive multi-dimension visualization, support multi-user collaborative work, and provide a natural way of perception and interaction between avatars or users, or between users and virtual environments. Thus, VGE can be an integrative innovation and its research contents may involve multi-discipline issues, such as geo-modeling, geographic simulation, GeoComputation, geo-visualization, computer network, geo-collaboration and interaction, geo-knowledge discovery and sharing, and virtual geographic experiments. Those are as well as the key issues of VGE research. On the other hand, VGE extends the research range of traditional geography with virtual extended geographic environments. Thus, the research contents of geography extend from place and space of real geographic environment to place-space and relationship in virtual environments or interaction between those two. This paper will discuss further on two extended research fields: Virtual Geography and Experimental Geography in the subsequent sections.

3 Revolution of Geography Research Methods and Geographic Languages

There has always been a thread of research thoughts of "Pattern - Structure - Process -Mechanism" throughout geography studies. However, the research methods in traditional physical geography are mostly field-site inspection and the use of maps and data analysis. Geographer Baranshiy once said, "Map is the second language of geography". Using maps for thinking and analyzing is the most important research method that makes geography different from other subjects. Development of GIS is based on a combination of map, mathematical methods, and modern information technologies. To date, GIS has become the most common carrier and platform of geographic information. Chen argued "GIS is the third-generation language of geography" [23].

Along with constant improvement of ability and means to access digital spatial data and expansion of GIS applications, limitation of traditional GIS (map-centered and data-driven mechanism) has hindered the development of new methods in the field of geographic information representation and services. Virtual reality technology can be used as an immersive human-computer interface for 3D visualization, collaborative work and group decision making through integration with traditional GIS and 3D GIS. Thus, development of VGE can be seen as a higher level of GIS that integrates traditional GIS, virtual reality, network technology, geo-models, human-computer interaction technology, and systematic methods. Lin argued VGE can be a new generation of geographic language in that VGE had the ability of abstract expression of multi-dimensional, multi-viewpoint, multiple details of multi-model visualization, supporting for a variety of natural interaction and multi-spatial cognition [4, 11]. Fig. 1 shows the developing process from map and GIS to VGE.

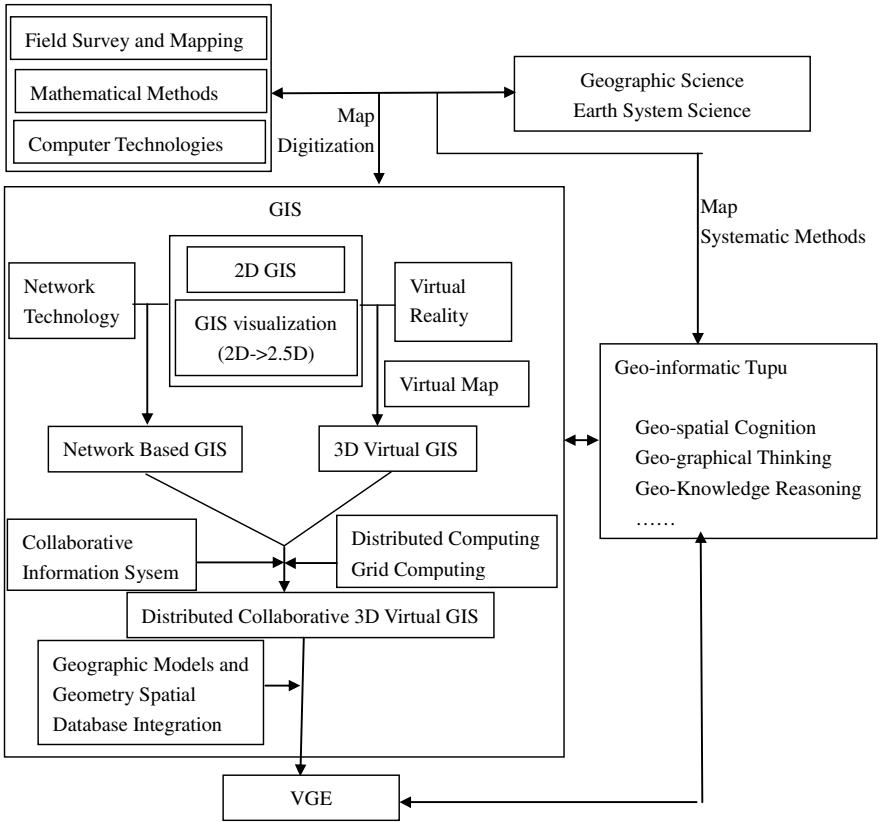


Fig. 1. Process from map and GIS to VGE

4 Development of Virtual Geography

4.1 VGE Extends Geographic Environment in the Real World

Geography is the science of place and space [24]. Traditional geography focuses on place and space of geographic environment in the real world. However, information science and technology provide open and distributed environments like VGE in the Internet or in other cyberspace. In those information worlds, the importance of geographic distance and place has gradually decreased [2]. Online communities or virtual companies exist in cyberspace with virtual places in virtual environments, but with their locations at “elsewhere” or even nowhere in the real world. Thus, space-place becomes virtual space-place and this leads to a deep thinking and wide discussion for geographers in the context of future geography [25, 26, 27, 28]. Geography Research has extended from traditional geographic environment to virtual geographic environments that Virtual Geography focuses on.

4.2 Virtual Geography

Virtual geography, cyber geography, and imagine geography are all the similar terms in the present literatures that show the impacts of modern technology on geography [2]. Batty proposed virtual geography and focused on the relationship and interaction between cyberspace and the real world, and argued that the boundary between space and place in cyberspace turned blurred, while Crang et al. examined virtual geography mainly from the aspect of complicated social relationships in virtual environments.

Lin and Gong [1, 2] argued that virtual geography was a new dimension of geography studying the characteristics and laws involving VGE, and the relationship and interaction between VGE and real geographic environments. In comparison to traditional geography, research contents of this new initiative of geography may include:

- 1, cybercartography: this is to study the principles and methodology of cyber-mapping.
- 2, Development, planning and building of 3D virtual worlds.
- 3, Spatial perception, cognition and behavior of post-human in 3D virtual environments.
- 4, Issues in the evolution process of VGE, such as boundary and relationship among various 3D virtual worlds, mechanism of driving forces of evolution of VGE, etc.
- 5, Relationship and interaction between VGE and real geographic environments in population, landscape, social, political, and economic structures.

5 Development of Experimental Geography

5.1 Experimental Geography

Experiment is an important feature as well as a symbol of development of modern science. That means a scientific experiment can be repeated and be verified. Experience, observation, practice, and experiment are of great importance in geography research. From 1950-1960, Chinese geographers have come to realize the importance of experiments for scientific theories and methods of geography development. Huang Bingwei, a modern Geography pioneer of China, pointed out that, the old methods such as empirical and descriptive study in geography research were inanimate, and Experimental Geography was a major development direction of the forward-looking geography [29].

Experimental Geography applies specific experimental ideas, experimental methods, observation equipments and instruments to learn about the spatial structure, time series, human-earth relationship of geographic environment, discover the basic law of geography information accumulation and provide evidence to form a measurable, comparable, controllable geographic system. Therefore, experimental design and experimental execution theories and methods together constitute the research contents of Experimental Geography. The purpose of all experimental work is to identify geographical relations through accessing geographic information by the means of an extension of human senses.

Traditional methods used in Experimental Geography include field experiments and indoor physical modeling and experiments. However, those traditional experimental methods show much limitation when its processed object, geographic system, is a complex giant system with geographic issues of multi-dimension, multi-scale, ambiguity and uncertainty. At present, geographic mathematical modeling, remote sensing information modeling and computer simulation calculation and experimental methods are various and complicated, thus, an organic integration of those modern methods from the perspective of Experimental Geography is needed to be achieved.

5.2 Virtual Geographic Experiments for Experimental Geography

Virtual experiments are defined as digital and virtual environments to carry out scientific experiments with the support of computer and network technologies. As development of information technology and simulation technology goes further, currently, virtual experiments are applied to a large number of research areas, including biology, chemistry, physics, human motion, and manufacturing, and has become a hot issue in those research fields. However, virtual experiment applications in geosciences are relatively few due to the giant system and highly complex nature of geographic environment. In recent years, as development of VGE and related research that has been carried out, as well as learning from virtual experiment applications in experimental economics, experimental medicine and other areas, virtual geographic experiment has gradually formed a new direction of research methods for Experimental Geography.

5.3 VGE as a Virtual Geographic Experiment Platform

We argue that VGE, a virtual geographic world, can be a virtual laboratory in which Virtual Geographic Experiment can be carried out. Virtual Geographic experiment aims to establish and visualize geographic models to verify and represent geographic phenomena and processes by calculation, simulation, visualization, real-time human participation, interaction and manipulation based on geosciences data. It may correspond to geographic positioning field experiments, or indoor physical modeling experiments. It may also be some virtually constructed experiments based on specific geographic features, phenomena and laws that are difficult to be carried out as physical experiments in the real world. Virtual Geographic Experiment can be widely used not only in traditional experimental geography focused research areas of physical geography, but also in economic geography and human geography as a major research method.

With the support of such an integration platform of interactive and collaborative work and geographic experimental environment provided by VGE, geographers can analyze the represented geographic phenomena and processes and carry out joint research, knowledge discovery, communication and decision-making in its immersive way. Thus, VGE extends the research methods of Experimental Geography (Fig. 2).

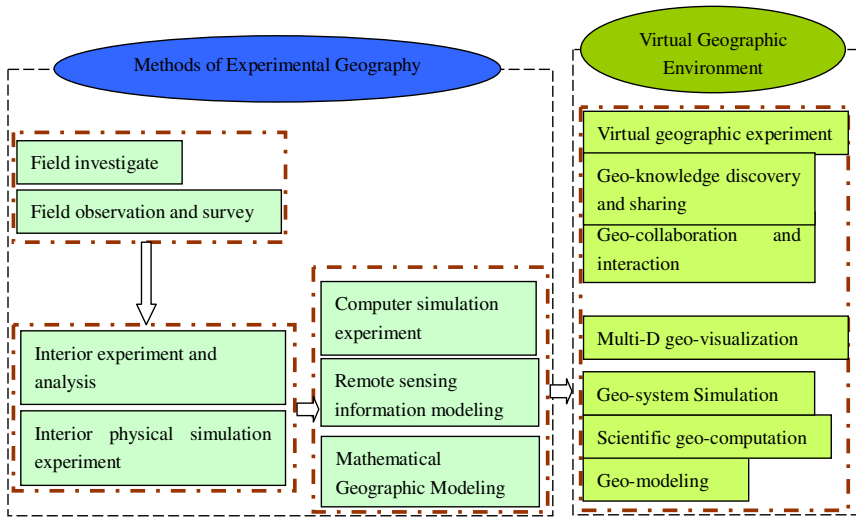


Fig. 2. VGE extends the research methods of Experimental Geography

6 Discussion and Conclusion

In recent years, multi-user virtual environments have come into widespread use on the Internet. Virtual environment technologies and virtual world platforms (e.g. the classical virtual world "Second Life"®) are used not only for games but also for various non-game purpose applications [30]. Moreover, Roush argued that the World Wide Web will soon be absorbed into the World Wide Sim: an immersive, 3D visual environment combining elements of social virtual worlds (e.g. Second Life®) and mapping applications (e.g. Google Earth), and what's coming is a larger digital environment-a 3D Internet [31]. Many relevant issues are being developed or need to be developed to explore both on theory, technology and various applications on those subjects. VGE combines elements of all these technologies and research on relevant frontier issues from the perspective of geography. However, current VGE research focuses more on geometry modeling and visualization or realistic representation that inherits and extends from 2D GIS functionalities, there are limitations with VGE but are important aspects of VGE are dynamic geographic processes modeling and visualization, geo-collaboration, interaction under a 3D virtual environments that support for the capability of people to better understand the real geographic environment.

Virtual Geography and Experimental Geography are two closest fields that associate with the development of VGE. Virtual Geography has VGEs as its research object and extend geographic issues from traditional geographic environment to virtual environments and the spaces, places, avatars, and all the other elements and relations in it. Experimental Geography might have VGE as a new medium to establish virtual experiments on geographic processes with a way of immersive visualization, geo-collaboration and natural interaction. Development of VGE represents a new field in

geographic information and geographic research in the coming 3D Internet age. Much work should be developed from different aspects of this new field.

Acknowledgements

This research is partially supported by The National “863” High Technology Research and Development Program of China (No. 2006AA12Z207, 2007AA120502), and Direct Grant from CUHK (No. 2020967). We would also like to thank the three anonymous reviewers for their valuable suggestions on previous version of this paper.

References

- [1] Gong, J., Lin, H.: *Virtual Geographic Environments—A Geographic Perspective on Online Virtual Reality*. High Education Press, Beijing (2001)
- [2] Lin, H., Gong, J.: Exploring Virtual Geographic Environments. *Geographic Information Sciences* 7(1), 1–7 (2001)
- [3] Lin, H., Gong, J.: On Virtual Geographic Environments. *Acta Geodaetica et Cartographica Sinica* 31(1), 1–6 (2002)
- [4] Lin, H., Gong, J., Shi, J.: From Maps to GIS and VGE—A Discussion on the Evolution of the Geographic Language. *Geography and Geo-Information Science* 19(4), 18–23 (2003)
- [5] Jiulin, S.: An Exploration of Virtual Recreation Environment on Resources and Environment Sciences. *Resources Science* 21(1), 1–8 (1999)
- [6] Jun, G., Yunjun, X., Xiong, Y.: *Application of Virtual Reality in Terrain Environment Simulation*. People’s Liberation Army Press, Beijing
- [7] Dykes, J., Moore, K., Wood, J.: Virtual environments for student field work using network components. *International Journal of Geographical Information Science* 13(4), 397–416 (1999)
- [8] Batty, M., Smith, A.: Virtuality and Cities: Definitions, Geographies, Designs. In: Fisher, P.F., Unwin, D.B. (eds.) *Virtual Reality in Geography*, pp. 270–291. Taylor and Francis, Abington (2002)
- [9] Lin, H., Xu, B.: Some Thoughts on Virtual Geographic Environments. *Geography and Geo-Information Science* 23(2), 1–7 (2007)
- [10] Batty, M.: Virtual Geography. *Future* 29(4/5), 337–352 (1997)
- [11] Lin, H., Zhu, Q.: The Linguistic Characteristics of Virtual Geographic Environments. *Journal of Remote Sensing* 9(2), 158–165 (2005)
- [12] Tang, W., Lv, G., Wen, Y., et al.: Study of Visual Geographic Modeling Framework for Virtual Geographic Environment. *Geo-information Science* 9(2), 78–84 (2007)
- [13] Jeong, B., Renambot, L., Jagodic, R., Singh, R., Aguilera, J., Johnson, A., Leigh, J.: High-Performance Dynamic Graphics Streaming for Scalable Adaptive Graphics Environment. In: *Proceedings of SC 2006, Tampa, FL, November 11-17 (2006)*
- [14] Johnson, A., Leigh, J., Morin, P., Van Keken, P.: GeoWall: Stereoscopic Visualization for Geoscience Research and Education. *IEEE Computer Graphics and Applications* (11/01/2006 - 12/31/2006)
- [15] MacEachren, A., Cai, G., Sharma, R., Rauschert, I., Brewer, I., Bolelli, L., Shaparenko, B., Fuhrmann, S., Wang, H.: Enabling collaborative Geoinformation access and decision-making through a natural, multimodal interface. *International Journal of Geographical Information Science* 19(3), 293–317 (2005)

- [16] Smith, H., Evanss, Batty, M.: Building the virtual city: Public participation through e-democracy. *Knowledge, Technology & Policy* 18(1), 62–85 (2005)
- [17] Keiji, Y.: Virtual Kyoto through 4D-GIS and Virtual Reality, <http://www.ritsumei.ac.jp/eng/newsletter/winter2006/gis.shtml>
- [18] <http://www.Earth.google.com>
- [19] <http://www.sketchup.google.com>
- [20] <http://www.preview.local.live.com>
- [21] <http://www.secondlife.com>
- [22] <http://www.opensimulator.org>
- [23] Chen, S.: Geographic Information System Exploration and Experiments. *Scientia Geographica Sinica* 3(4), 287–302 (1983)
- [24] AAG, What is a geography (2001), <http://www.aag.org/>
- [25] Couclelis, H.: he Death of Distance. *Environment and Planning B: Planning and Design* 23, 387–398 (1996)
- [26] NCGIA, Project Varenius (1998), <http://www.ncgis.ucsb.edu/varenius/>
- [27] Crang, M., Crang, P., May, J.: Introduction in *Virtual Geography: Bodies, Space, and Relations*. In: Crang, M., Crang, P., May, J. (eds.), pp. 1–20. Routledge, London (1999)
- [28] Dodge, M.: Cybergeography. *Environment and Planning B: Planning and Design* 28, 1–2 (2001)
- [29] Tang, D.: Experimental Geography and Geographical Engineering. *Geographical Research* 16(1), 1–10 (1997)
- [30] Quinn, B.: Immersive 3D Simulator-based GIS. *Bay Area Automated Mapping Association*, 3–16 (2009)
- [31] Roush, W.: Second Earth. *Technology Review* 7/8, 39–48 (2007)