Preprint: Virtual Reality Assistant Technology for Learning Primary Geography

Zhihan Lv$^1$ and Xiaoming Li$^{1,2,3}$

1. Shenzhen Institutes of Advanced Technology, Chinese Academy of Science, China.
2. Shenzhen Research Center of Digital City Engineering, Shenzhen, China
3. Key Laboratory of Urban Land Resources Monitoring and Simulation, Ministry of Land and Resources, Shenzhen, China
lvzhihan@gmail.com

Abstract. This is the preprint version of our paper on ICWL2015. A virtual reality based enhanced technology for learning primary geography is proposed, which synthesizes several latest information technologies including virtual reality(VR), 3D geographical information system(GIS), 3D visualization and multimodal human-computer-interaction (HCI). The main functions of the proposed system are introduced, i.e. Buffer analysis, Overlay analysis, Space convex hull calculation, Space convex decomposition, 3D topology analysis and 3D space intersection detection. The multimodal technologies are employed in the system to enhance the immersive perception of the users.

Keywords: VRGIS, Geography Learning, Virtual Reality, GIS

1 Introduction

With the developments in web, mobile and virtual reality technologies as well as mass adoption of smart and mobile devices by all people in the current society, significant opportunities have emerged for e-learning applications [16]. Location-based mobile phone software has been proved to have the potential in supporting biology, geography and math lessons for students in schools [12]. The latest technologies from video game industry make it becomes easy and efficient to integrate the state-of-the-art graphics/interface and the educational aspect with poor graphics and interaction [1] [25]. The technologies of video games have attracted considerable attention to enhance user participation and motivation which should be a key concern in the design of an interactive human-computer-interaction(HCI) interface [5] of the learning enhanced system [10]. Technology enhanced learning brings multidisciplinary, interdisciplinary, and pandisciplinary educational content in different forms [2] oriented to different culture [40]. The dynamic learning environments can deliver educational benefits as educational offerings based upon various characteristics of individual learners [27]. Synthesizing multimedia operations and knowledge sharing aspects has also attracted attention from the research community [15]. The combinations of technology enhanced learning and other applied information field have been considered as promising practical research topics [36]. It has been argued that integration of
In virtual reality technology trend, geospatial data visualization has never been developing rapidly [34]. With the development of VR (Virtual Reality) technology and widely applications in various areas, the requirements to VR are also increasing rapidly. Virtual Reality Geographical Information System (VRGIS), a combination of geographic information system and virtual reality technology [14] has become a hot topic. Accordingly, '3-D modes' has been proved as a faster decision making tool with fewer errors [33]. Meanwhile, new user interfaces for geo-databases is also expected [3]. With the popularity of network, the VRGIS platform based on the network environment also becomes a trend. The application of VRML, X3D and other online VR technologies have achieved networking of VR systems [37] [23] [21] [20].

WebVRGIS is preferred in practical applications, especially by the geography and urban planning [22] [19], which is based on WebVR [24]. Urban simulation is becoming widely noticed nowadays, and some simulation systems have been developed in this area, e.g. ArcView3D Analyst, Imagine Virtual GIS, GeoMedia, etc. WebVRGIS engine supports steadily real time navigation in virtual scenes which are constructed with massive, multi-dimensional data from various sources [55] [18] [47] [54] [46] [17] [48] [44] [45] [32] [53] [49] [50] [42] [43] [51].

3D urban landscape database with various data sources can be produced to implement spatial analysis and 3D visualization and published in the Internet environment [11] [7] [8]. In this research, we plan to use virtual reality geographic information system technology as an education tool to teach the geography courses.

2 System Overview

3D geometrical analysis education model includes 8 sub-modules: entity set operation, buffer analysis, overlay analysis, space convex hull calculation, space convex decomposition, 3D topology analysis, 3D Minkowski sum calculation, and 3D space intersection detection, as shown in figure 1.

3 Functions

Entity set operation includes 4 sub-modules: union, meet, difference, and equilibrium difference. In the space entity, union outputs a new entity including all input entities. Meet outputs the common part of all input entities. Difference outputs spatial features included in the former input entity but excluded from the next space entity.

Buffer analysis includes point, line, face, and body. Buffer analysis is served as one of spatial analysis tools used to solve proximity-related problems. It is used
Fig. 1. 3D Geometrical Analysis Model

Fig. 2. Overlay Analysis
to realize spatial extension of a spatial entity, determine the scope of influence of this entity in 3D space, and reflect the gradual change law of its influence with distance variation. For instance, the buffer of special sphere with the radius as r (buffer distance R) is a ball with the radius as r+R.

Overlay analysis refers to an analytical method in which two or more geographic element photos in the same region are overlapped under a unified spatial reference system to generate multiple attributive characters of this region. Overlay analysis can be used for new classification of multiple attributes generated after such overlay, so as to establish spatial correspondence among geological objects, and extract quantitative characteristics of some topics within the scope of a certain region.

Space convex hull calculation: in 3D figure application, we often encounter such an issue: determine a convex polyhedron with the minimum volume and including several given points in the space. It is also a form of the minimum coverage problems to calculate the algorithm of convex hull including spatial point sets. It is widely applied in the modeling of buildings.

Space convex decomposition: convex decomposition of a concave polygon is one of basic problems about computation geometry. It is applied in many fields. It realizes the function of decomposing complicated space convex into simple convex polygon. Most existing algorithms are of overall decomposition algorithm. However, fewer researches are made on partial decomposition algorithm. The overall decomposition algorithm is time-consuming. Therefore, it cannot meet application needs of all projects.

3D topology analysis: space topological relation is an important part of spatial analysis. How to effectively generate and judge space topological relation has direct impact on the efficiency of spatial information system. The establishment of 3D topological relation makes it easy to realize various space operations and information inquiry. Complicated surface features can be described with various bodies filled in the space, hook faces constituting those bodies, boundary rings constituting those hook faces, arcs constituting those rings, and nodes on those arcs. Generally speaking, body is basic constitution for the target entity. Any complicated entities are deemed as composed of bodies (natural or artificial). Body, face, line and point are dynamic concepts. They are interconvertible under different scales or different research emphases. The following 6 groups of relations are used to describe the space topological relation of 3D vector structure in the spatial information system: relation between complicated surface feature and body, relation among body, complicated surface feature, and hook face, relation among hook face, ring, and body, relation among ring, arc and hook face, relation among arc, node, and ring, and relation between node and arc.

3D space intersection detection: while simulating 3D animation scenes, numerous collision phenomena will be encountered. Essentially, these collision phenomena are points, lines, faces, and bodies. It is only necessary to judge whether they intersect in 3D space, and work out intersecting points, intersecting lines, intersecting faces, and intersecting bodies.
4 Application Scenarios

The oriented city region simulation WebVRGIS engine is developed based on OpenGL and C++, which integrates VR and GIS seamlessly and supports massive data.

As shown in figure 4, the user is watching the virtual geographical scene through the HMD. The HMD is the VR glasses shell by which users could watch the anaglyph 3D scene generated from smartphone screen. The convergence-to-face part of the HMD for light blocking is made by soft holster filling of sponge, so it's not oppressive at all. In addition, it can modify the pupil distance (PD) and depth of field (DOF), so it is suitable for the users with different myopia degree and PD. The input methods include head motion and remote controller. The head motion on VR glasses only supports the rotations around three axis which are controlled by gyroscope sensor of the smartphone. The head rotation actions are synchronous with the rotation of the camera view in the VR scene, which brings the immersive perception to the user in real time. Meanwhile, the remote controller is used to input the displacement of the 3D scene as well as manipulate the menu of the software configuration.

5 Conclusion

WebVRGIS is used to show the geographical information intuitively as an enhanced learning tool. Geographical information has several characteristics, i.e., large scale, diverse predictable and real-time, which falls in the range of definition of Big Data defined by Faye Briggs [4]. Virtual reality is a promising and suitable technology to represent geographical bigdata. In future, the new technology will enhance the learning process, for example, multiple users may support the teacher to train a class at the same time.

Fig. 3. VRGIS Running on Virtual Reality Glassess Device
Fig. 4. Left: the user wears the virtual reality Glasses to look at the virtual 3D GIS; Right: the user wears the virtual reality Glasses and use touch-less interaction to manipulate the 3D GIS.

References

1. F. Bellotti, R. Berta, A. D. Gloria, and L. Primavera. Enhancing the educational value of video games. *Computers in Entertainment (CIE)*, 7(2):23, 2009.
2. P. Boytchev, K. Kanev, and R. Nikolov. Technology enhanced learning with subject field multiplicity support. In *Proceedings of the 2012 Joint International Conference on Human-Centered Computer Environments*, pages 39–44. ACM, 2012.
3. M. Breunig and S. Zlatanova. Review: 3d geo-database research: Retrospective and future directions. *Comput. Geosci.*, 37(7):791–803, July 2011.
4. F. Briggs. Large data - great opportunities. Presented at IDEF2012, Beijing, 2012.
5. W.-P. Brinkman, C. van der Mast, A. Payne, and J. Underwood. Hdi for technology enhanced learning. In *Proceedings of the 22nd British HCI Group Annual Conference on People and Computers: Culture, Creativity, Interaction-Volume 2*, pages 185–186. British Computer Society, 2008.
6. J. M. Carroll and M. B. Rosson. A case library for teaching usability engineering: Design rationale, development, and classroom experience. *Journal on Educational Resources in Computing (JERIC)*, 5(1):3, 2005.
7. L. Che, M. Shahidehpour, A. Alabdulwahab, and Y. Al-Turki. Hierarchical coordination of a community microgrid with ac and dc microgrids. *Smart Grid, IEEE Transactions on*, PP(99):1–1, 2015.
8. L. Che, X. Zhang, M. Shahidehpour, A. Alabdulwahab, and A. Abusorrah. Optimal interconnection planning of community microgrids with renewable energy sources. *Smart Grid, IEEE Transactions on*, PP(99):1–1, 2015.
9. Y.-C. Chen. A study of comparing the use of augmented reality and physical models in chemistry education. In *Proceedings of the 2006 ACM international conference on Virtual reality continuum and its applications*, pages 369–372. ACM, 2006.
10. Z.-H. Chen and S. Y. Chen. A surrogate competition approach to enhancing game-based learning. *ACM Transactions on Computer-Human Interaction (TOCHI)*, 20(6):35, 2013.
11. S. Dang, J. Ju, D. Matthews, X. Feng, and C. Zuo. Efficient solar power heating system based on lenticular condensation. In *Information Science, Electronics and Electrical Engineering (ISEE), 2014 International Conference on*, volume 2, pages 736–739. IEEE, 2014.
12. F. A. Hansen, K. J. Kortbek, and K. Grønbæk. Mobile urban drama for multimedia-based out-of-school learning. In *Proceedings of the 9th International
13. A. Holzinger, M. D. Kickmeier-Rust, and M. Ebner. Interactive technology for enhancing distributed learning: a study on weblogs. In Proceedings of the 23rd British HCI Group Annual Conference on People and Computers: Celebrating People and Technology, pages 309–312. British Computer Society, 2009.

14. B. Huang, B. Jiang, and H. Li. An integration of gis, virtual reality and the internet for visualization, analysis and exploration of spatial data, 2001.

15. R. Klamma, M. Spaniol, and M. Jarke. Knowledge multimedia processes in technology enhanced learning. In Proceedings of the first ACM international workshop on Multimedia technologies for distance learning, pages 77–86. ACM, 2009.

16. J. Lahti, E. Siira, and V. Törnänen. Development and evaluation of media-enhanced learning application. In Proceedings of the 11th International Conference on Mobile and Ubiquitous Multimedia, page 5. ACM, 2012.

17. T. Li, X. Zhou, K. Brandstatter, and I. Raiu. Distributed key-value store on lpc and cloud systems. In 2nd Greater Chicago Area System Research Workshop (GCASR). Citeseer, 2013.

18. T. Li, X. Zhou, K. Brandstatter, D. Zhao, K. Wang, A. Rajendran, Z. Zhang, and I. Raiu. Zht: A light-weight reliable persistent dynamic scalable zero-hop distributed hash table. In Parallel & Distributed Processing (IPDPS), 2013 IEEE 27th International Symposium on, pages 775–787. IEEE, 2013.

19. X. Li, Z. Lv, J. Hu, B. Zhang, L. Shi, and S. Feng. Xearth: A 3d gis platform for managing massive city information. In Computational Intelligence and Virtual Environments for Measurement Systems and Applications (CIVEMSA), 2015 IEEE International Conference on, pages 1–6. IEEE, 2015.

20. X. Li, Z. Lv, J. Hu, B. Zhang, L. Yin, C. Zhong, W. Wang, and S. Feng. Traffic management and forecasting system based on 3d gis. In 15th IEEE/ACM International Symposium on Cluster, Cloud and Grid Computing (CCGrid). IEEE, 2015.

21. Z. Lv, X. Li, B. Zhang, W. Wang, S. Feng, and J. Hu. Big city 3d visual analysis. In 36th Annual Conference of the European Association for Computer Graphics (Eurographics2015). European Association for Computer Graphics, 2015.

22. Z. Lv, S. Rhman, and G. Chen. Webvgis: A p2p network engine for vr data and gis analysis. In M. Lee, A. Hirose, Z.-G. Hou, and R. Kil, editors, Neural Information Processing, volume 8226 of Lecture Notes in Computer Science, pages 503–510. Springer Berlin Heidelberg, 2013.

23. Z. Lv and T. Su. 3d seabed modeling and visualization on ubiquitous context. In SIGGRAPH Asia 2014 Posters, page 33. ACM, 2014.

24. Z. Lv, T. Yin, Y. Han, Y. Chen, and G. Chen. Webvr–web virtual reality engine based on p2p network. Journal of Networks, 6(7), 2011.

25. M. J. Mayo. Games for science and engineering education. Communications of the ACM, 50(7):30–35, 2007.

26. S. Minocha and C. L. Hardy. Designing navigation and wayfinding in 3d virtual learning spaces. In Proceedings of the 23rd Australian Computer-Human Interaction Conference, pages 211–220. ACM, 2011.

27. C. Mulwa, S. Lawless, M. Sharp, I. Arnedillo-Sanchez, and V. Wade. Adaptive educational hypermedia systems in technology enhanced learning: a literature review. In Proceedings of the 2010 ACM conference on Information technology education, pages 73–84. ACM, 2010.

28. B. Mustafa. Visualizing the modern operating system: simulation experiments supporting enhanced learning. In Proceedings of the 2011 conference on Information technology education, pages 209–214. ACM, 2011.

29. T. Nagel, E. Duval, and A. Vande Moere. Interactive exploration of geospatial network visualization. In CHI’12 Extended Abstracts on Human Factors in Computing Systems, pages 557–572. ACM, 2012.

30. K. Ng. Interactive feedbacks with visualisation and sonification for technology-enhanced learning for music performance. In Proceedings of the 26th annual ACM international conference on Design of communication, pages 281–292. ACM, 2008.
31. D. Paneva-Marinova, L. Pavlova-Driganova, L. Draganov, and V. Georgiev. Ontological presentation of analysis method for technology-enhanced learning. In Proceedings of the 13th International Conference on Computer Systems and Technologies, pages 384–390. ACM, 2012.
32. R. Pintus, K. Pal, Y. Yang, T. Weyrich, E. Gobbetti, and H. Rushmeier. A survey of geometric analysis in cultural heritage. Computer Graphics Forum, 2015.
33. T. Porathe and J. Prison. Design of human-map system interaction. In CHI ’08 Extended Abstracts on Human Factors in Computing Systems, CHI EA ’08, pages 2859–2864, New York, NY, USA, 2008. ACM.
34. T. M. Rhyne and A. MacEachren. Visualizing geospatial data. In ACM SIGGRAPH 2004 Course Notes, page 31. ACM, 2004.
35. E. Scanlon, T. O’Shea, and P. McAndrew. Technology-enhanced learning: evidence-based improvement. 2015.
36. M. Schmees. Organizing technology enhanced learning. In Proceedings of the 8th international conference on Electronic commerce: The new e-commerce: innovations for conquering current barriers, obstacles and limitations to conducting successful business on the internet, pages 139–150. ACM, 2006.
37. T. Su, Z. Lv, S. Gao, X. Li, and H. Lv. 3d seabed: 3d modeling and visualization platform for the seabed. In Multimedia and Expo Workshops (ICMEW), 2014 IEEE International Conference on, pages 1–6. IEEE, 2014.
38. B. Tomaszewski and E. Holden. The geographic information science and technology information technology bodies of knowledge: an ontological alignment. In Proceedings of the 13th annual conference on Information technology education, pages 195–200. ACM, 2012.
39. J. Underwood. Designing technology enhanced learning contexts. In Proceedings of the 9th international conference on Computer supported collaborative learning-Volume 2, pages 270–272. International Society of the Learning Sciences, 2009.
40. R. Vatrapu. Cultural considerations in learning analytics. In Proceedings of the 1st International Conference on Learning Analytics and Knowledge, pages 127–133. ACM, 2011.
41. K. Walczak, R. Wojciechowski, and W. Cellary. Dynamic interactive vr network services for education. In Proceedings of the ACM symposium on Virtual reality software and technology, pages 277–286. ACM, 2006.
42. J. J.-Y. Wang and X. Gao. Partially labeled data tuple can optimize multivariate performance measures. In 24th ACM International Conference on Information and Knowledge Management (CIKM 2015), 2015.
43. J. J.-Y. Wang, Y. Wang, B.-Y. Jing, and X. Gao. Regularized maximum correntropy machine. Neurocomputing, 160:85–92, 2015.
44. K. Wang, A. Kullarni, X. Zhou, M. Lang, and I. Raicu. Using simulation to explore distributed key-value stores for exascale system services. In 2nd Greater Chicago Area System Research Workshop (GCASR), 2013.
45. K. Wang, N. Liu, I. Sadooghi, X. Yang, X. Zhou, M. Lang, X.-H. Sun, and I. Raicu. Overcoming hadoop scaling limitations through distributed task execution.
46. K. Wang, X. Zhou, H. Chen, M. Lang, and I. Raicu. Next generation job management systems for extreme-scale ensemble computing. In Proceedings of the 23rd international symposium on High-performance parallel and distributed computing, pages 111–114. ACM, 2014.
47. K. Wang, X. Zhou, T. Li, D. Zhao, M. Lang, and I. Raicu. Optimizing load balancing and data-locality with data-aware scheduling. In Big Data (Big Data), 2014 IEEE International Conference on, pages 119–128. IEEE, 2014.
48. K. Wang, X. Zhou, K. Qiao, M. Lang, B. McClelland, and I. Raicu. Towards scalable distributed workload manager with monitoring-based weakly consistent resource stealing. In Proceedings of the 24rd international symposium on High-performance parallel and distributed computing, pages 219–222. ACM, 2015.

49. Y. Wang, T. Bicer, W. Jiang, and G. Agrawal. Smart: A mapreduce-like framework for in-situ scientific analytics, 2015.

50. Y. Wang, Y. Su, and G. Agrawal. A novel approach for approximate aggregations over arrays. In Proceedings of the 27th International Conference on Scientific and Statistical Database Management, page 4. ACM, 2015.

51. Y. Yang and I. Ivrissimitzis. Mesh discriminative features for 3d steganalysis. ACM Trans. Multimedia Comput. Commun. Appl., 10(3):27–1, 2014.

52. N. Yannier, K. R. Koedinger, and S. E. Hudson. Learning from mixed-reality games: Is shaking a tablet as effective as physical observation? In Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems, pages 1045–1054. ACM, 2015.

53. S. Zhang, X. Zhang, and X. Ou. After we knew it: empirical study and modeling of cost-effectiveness of exploiting prevalent known vulnerabilities across iaas cloud. In Proceedings of the 9th ACM symposium on Information, computer and communications security, pages 317–328. ACM, 2014.

54. D. Zhao, Z. Zhang, X. Zhou, T. Li, K. Wang, D. Kimpe, P. Carns, R. Ross, and I. Raicu. Fusionfs: Toward supporting data-intensive scientific applications on extreme-scale high-performance computing systems. In Big Data (Big Data), 2014 IEEE International Conference on, pages 61–70. IEEE, 2014.

55. X. Zhou, H. Chen, K. Wang, M. Lang, and I. Raicu. Exploring distributed resource allocation techniques in the slurm job management system. Illinois Institute of Technology, Department of Computer Science, Technical Report, 2013.