Real-time Interactive Groundwater Visualization using 3D Cellular Automata

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Abstract

Groundwater is an inherently three dimensional concept commonly communicated through diagrams in text books, educational posters or rendered in groundwater modeling software (Cherry and Freeze, 1979; Todd and Mays 2004; Fritts 2002; Schwartz and Zhang 2002; Turner et al., 2006, Li and Liu, 2004). In an attempt to improve existing communication tools we developed an interactive groundwater model prototype designed to encourage discussion and participation of Okanagan Basin (OB) stakeholders in their decision making processes. CABI (Cellular Automata Basin Interface) provides non experts a first glimpse of the relationships between groundwater, wells, and rivers. CABI gives OB stakeholders a 3D interactive experience allowing manipulation of the terrain and placement of wells. Water is implemented using cellular automata (CA) modelling which allows real-time changes in water levels adapting to wells and their surroundings. Testing by 43 participants to discern performance effects due to variations in manipulation controls showed differences in task completion times.

Background and Relevance

The Okanagan Basin (OB), one of Canada's driest regions, has limited water recharge despite the apparent abundance of lake water. With an increasing population and most surface water already allocated groundwater is seen as an alternative. Communicating to OB stakeholders the relationships between groundwater and surface water can help bring consensus and encourage dialogue regarding sustainable growth, water conservation and protection. Public groundwater education methods have largely relied on traditional mediums. This project attempts to bring an interactive sandbox environment to stakeholders by implementing cellular automata (CA) modeling, and geovisualization principles to communicate groundwater concepts. This research project also utilizes CABI to explore the effects of differences in model manipulation and visualization. Cellular automata modelling, created by von Neumann (1966) and popularized by Stephen Wolfram (1983), is a relatively new and powerful method of modelling complex systems. Cellular Automata is a form of aggregate complexity where simple local interaction between components or cells creates a complex system (Mason, 2001).

Methods and Data

This project focuses on the creation of a desktop 3D environment driven by CA engine to control the behaviour of water and uses geovisualization principles for the manipulation and interaction with the model. The resulting sandbox environment allows simple interaction with a seemingly simple but hidden complex system. In addition to the design project, three lab sections of an introductory geography class supplied 43 volunteers for testing. While all completing the same task, half of the participants used version of CABI with constrained visualization controls.

Results

CABI successfully simulates river flow, base flow, and cones of depression due to well placements. All changes occur in real-time allowing target stakeholders to explore interaction between sub surface and surface water in a robust virtual sandbox environment. Statistical comparisons between samples show little measurable change with the exception of significantly faster completion times for participants using constrained versions of CABI.

Conclusions

Using CA to model water behaviour in geovisualization environment brings models commonly used by scientists for research to stakeholders. While primitive and graphically simple the complex system resulting from a CA design allows for an immersive and interactive experience that can bring consensus between expert and non-experts. While testing compared model manipulation controls and found few significant differences, more testing is required to determine the efficacy of CABI relative to classic educational methods. CABI is however an immersive experience that can be enjoyable and foster discussion regarding the connections between surface and sub surface water.

References

Freeze, A. R., & J. A. Cherry. (1979). *Groundwater*. New Jersey: Prentice Hall.

Fritts, C. R. (2002). *Groundwater Science*. Bath, UK: Bath Press.

Schwartz, F. W., & H. Zhang. (2002). *Fundamentals of Ground Water*. Alameda (CA): Wiley Publishers.

Todd, D. K., & L. W. Mays. (2005). *Groundwater hydrology*. (3rd ed.). Hoboken (NJ): Wiley.

Turner, R. J. W., R. G. Franklin, B. Taylor, M. Ceh, S. E. Grasby, B. Symonds, et al. (2006). Okanagan Basin Waterscape. Geological Survey of Canada, Miscellaneous Report 93.

Li, S., & Q. Liu. (2004). Interactive Groundwater (IGW): An Innovative Digital Laboratory for Groundwater Education and Research. *Environmental Modeling and Software*, 20(12): 179-202.

Mason, S. M. (2001). Simplifying complexity: a review of complexity theory. *Geoforum*, 32(3): 405-414.

von Neumann, J. (1966). *Theory of Self-Reproducing Automata*. Champaign (IL): University of Illinois Press.

Wolfram, S. (1983). Cellular Automata. *Los Alamos Science*, 9(Fall 1983): 2-21.