Incorporating D3.js Information Visualization into Immersive Virtual Environments

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Abstract

We have created an integrated interactive visualization and analysis environment that can be used immersively or on the desktop to study a simulation of microstructure development during hydration or degradation of cement pastes and concrete. Our environment combines traditional 3D scientific data visualization with 2D information visualization using D3.js running in a web browser. By incorporating D3.js, our visualization allowed the scientist to quickly diagnose and debug errors in the parallel implementation of the simulation.

Keywords: immersive virtual environment; d3.js

Index Terms: H.1.2 [Models and Principles]: User/Machine Systems—Human information processing; H.5.1 [Information Interfaces and Presentation]: User Interfaces—Artificial, augmented, and virtual realities;

1 Introduction

Concrete provides strength and structure to a large part of our world. The cement binder in concrete undergoes multiple interacting chemical and structural changes as it transforms from a liquid suspension to a solid mass. Understanding the nature of these transformations is important for building a sustainable civil infrastructure. The Inorganic Materials Group within the Engineering Laboratory at NIST is developing parallel computational models capable of predicting the flow, hardening, and strength of cement.

To help understand and validate the models, we have developed an interactive visualization and analysis environment for the model output. Our environment provides a variety of visual modes that enable precise quantitative measurements. We also combine 3D scientific data visualization with information visualization using D3.js running in a web browser. We found that incorporating 2D methods allowed for faster model debugging and validation.

2 Architecture

Our architecture, illustrated in Figure 1 has three pieces:

1. **IRIS**: the immersive 3D scientific data visualization component

2. **D3.js**: the browser-based 2D information visualization component

3. **Node.js**: the bidirectional communication server

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In the figure, processes are squares, message queues are cylinders, user interface windows are squares with titlebars, and data flows are arrows colored based on the direction: red for data into **IRIS** and blue for data into **D3.js**.

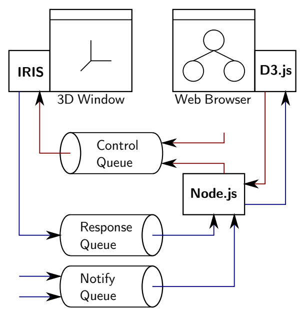

Figure 1: Architecture

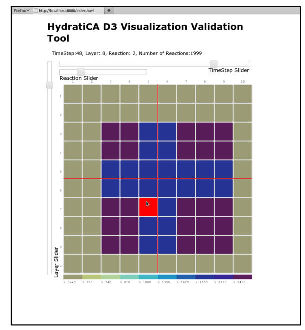

Figure 2: Initial Prototype

3 Prototype

Our prototype, illustrated in Figure 2, is a heat-map of the model output illustrating the spatial decomposition of the parallel implementation is on the right. The heat-map immediately revealed implementation issues in the parallel implementation, specifically the ghost layers. This bug is seen as the blue cross. The red line highlights the spatial decomposition and the blue cross indicates the ghost layers are not properly communicating. The scientist quickly fixed the communication error.

4 Results

Figure 3 shows the current 3D data visualization (**IRIS**) and Figure 4 shows the 2D information visualization (**D3.js**) windows. The 3D visualization shows the full simulation grid while the 2D visualization shows a single z-layer of the grid. The z-layer of the grid currently being viewed in the 2D visualization is rendered opaque in the 3D visualization and colored with the same set of colors in both windows. The specific cell that the mouse is hovering over in the 2D visualization is highlighted in gray in the 3D window. The 2D information visualization is composed of three parts: 1) a heat-map of activations for one component of the reaction network at a specific layer, 2) a histogram of all of the activations for one component at a specific time-step, and 3) the reaction network being simulated. As different layers and reactions are viewed, **D3.js** updates **IRIS**.

HydratiCA[1] is a parallel numerical simulation of the cement hydration process designed to run on distributed memory machines. The software is parallelized with a spatial decomposition and the

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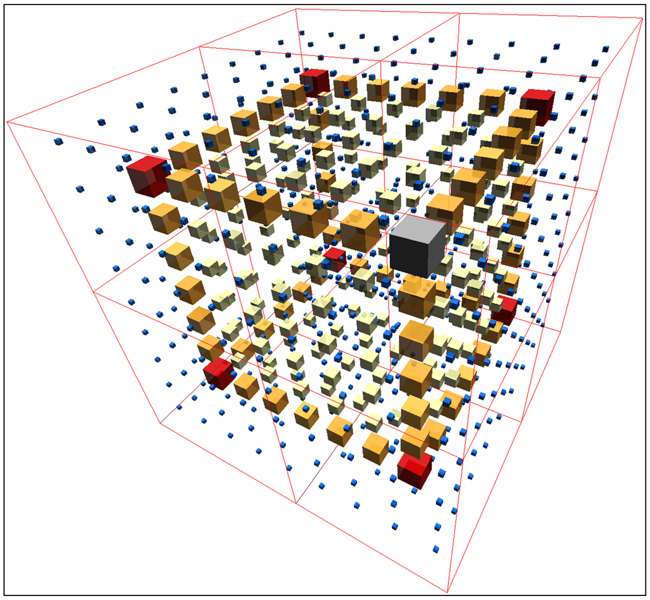

Figure 3: 3D Data Visualization

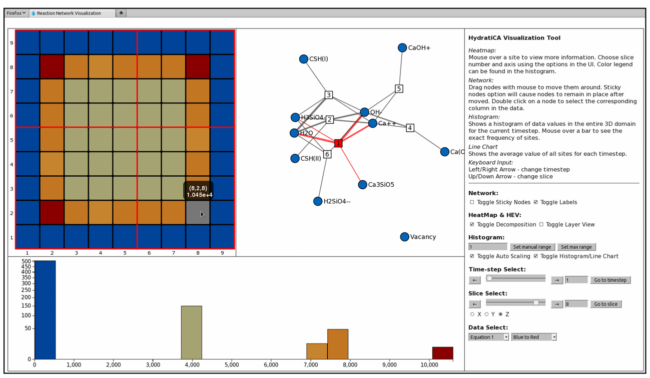

Figure 4: 2D Information Visualization

boundary layers between the processors are transferred into *ghost* layers for the iterative updates. Recent modifications to the code, however, were yielding questionable results due to implementation bugs. Our initial prototype revealed the ghost layer communication bugs. As the prototype was extended to include the histogram, a numerical stability issue was revealed where the activation rate for certain components was exponentially growing over time. Again, the visualization quickly pinpointed the location in the code that needed to be fixed.

5 Conclusion

We have presented an integrated interactive visualization environment that can be used immersively or on the desktop and combines 3D scientific data visualization and 2D information visualization. Both visualization components are interactive and support bi-directional updates. Our combined visualization revealed implementation issues in the computational model. These issues were quickly pinpointed by the scientist and the implementation was corrected.

6 Future Work

We are currently extending this visualization into a more general tool that can be used on datasets of varying size and spatial decomposition. This version displays the 2D information visualization directly in our immersive environment. We plan on incorporating a hand-held tablet to display the 2D visualization thus leaving more display space for the immersive 3D data visualization. We also plan on applying this technique to additional data sets.

7 Acknowledements

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References

[1] J. W. Bullard, E. Enjolras, W. L. George, S. G. Satterfield, and J. E. Terrill. A parallel reaction-transport model applied to cement hydration and microstructure development. *Modelling and Simulation in Materials Science and Engineering*, 18(2):025007:1–16, 2010.

[2] J. W. Bullard, E. J. Garboczi, W. L. George, N. S. Martys, S. G. Satterfield, and J. E. Terrill. Advancing the materials science of concrete with supercomputers. *Concrete International*, 33(1):24–29, Jan. 2011.

[3] J. E. Devaney, S. G. Satterfield, J. G. Hagedorn, J. T. Kelso, A. P. Peskin, W. L. George, T. J. Griffin, H. K. Hung, and R. Kriz. Science at the speed of thought. In Y. Cai, editor, *Ambient Intelligence for Scientific Discovery*, volume 3345 of *Lecture Notes in Computer Science*, pages 1–24. Springer, 2005.

[4] J. G. Hagedorn, J. Dunkers, S. G. Satterfield, A. P. Peskin, J. T. Kelso, and J. E. Terrill. Measurement tools for the immersive visualization environment: Steps toward the virtual laboratory. *Journal of Research of NIST*, 112(5):257–270, 2007.

[5] J. E. Terrill, W. L. George, T. J. Griffin, J. G. Hagedorn, J. T. Kelso, M. Olano, A. P. Peskin, S. G. Satterfield, J. S. Sims, J. W. Bullard, J. Dunkers, N. S. Martys, A. O'Gallagher, and G. Haemer. Extending measurement science to interactive visualisation environments. In R. Liere, T. Adriaansen, and E. Zudilova-Seinstra, editors, *Trends in Interactive Visualization*, Advanced Information and Knowledge Processing, pages 287–302. Springer London, 2009.