Unconventional Mappings for Visual Analysis of Large Data

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Maximizing the Information Bandwidth in Images for Graphics, Visualization, and Situation Awareness Applications

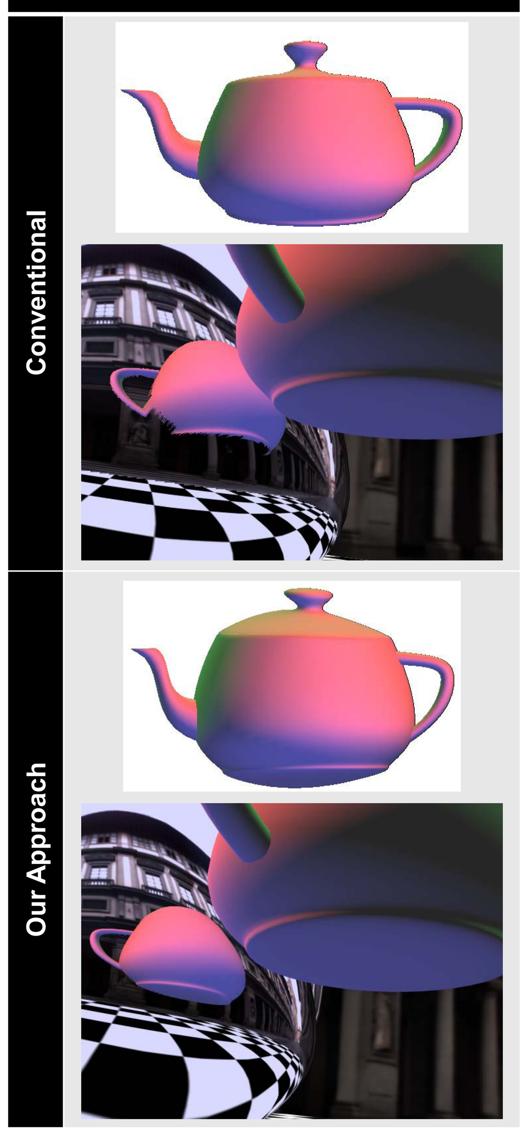
In collaboration with Wathsala Widanagamaachchi, Voicu Popescu (Purdue University), and Valerio Pascucci

Most images are produced using the perspective projection because the images are familiar to users and have simple and efficient implementations. There are two key limitations of perspective projection which reduces its visual bandwidth in an image. (1) Perspective projection requires direct line-of-sight to sample an object. (2) The regions sampled by the camera model is captured in a uniform manner.

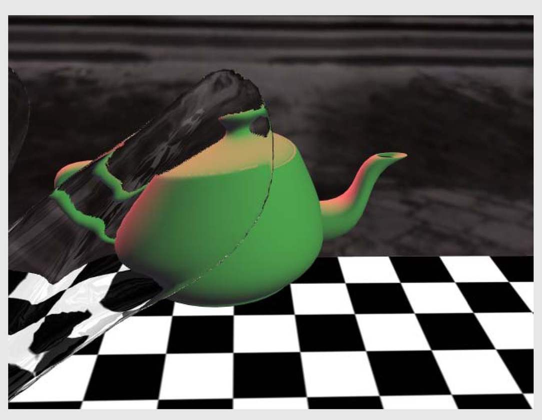
By removing these constrains and no longer requiring rays be straight, converge, or sample space uniformly, the visual bandwidth of images can be increased thereby creating more comprehensive visualizations. To achieve this, camera models are designed for specific applications and optimized dynamically based on the data at hand. These new images can be used as an intermediate representation, such as those used in remote visualization, or for direct viewing by the user. In general, these camera models have been designed to be efficient such that they can visualize dynamic datasets at interactive rates.

Computer Graphics

Reflections[1]

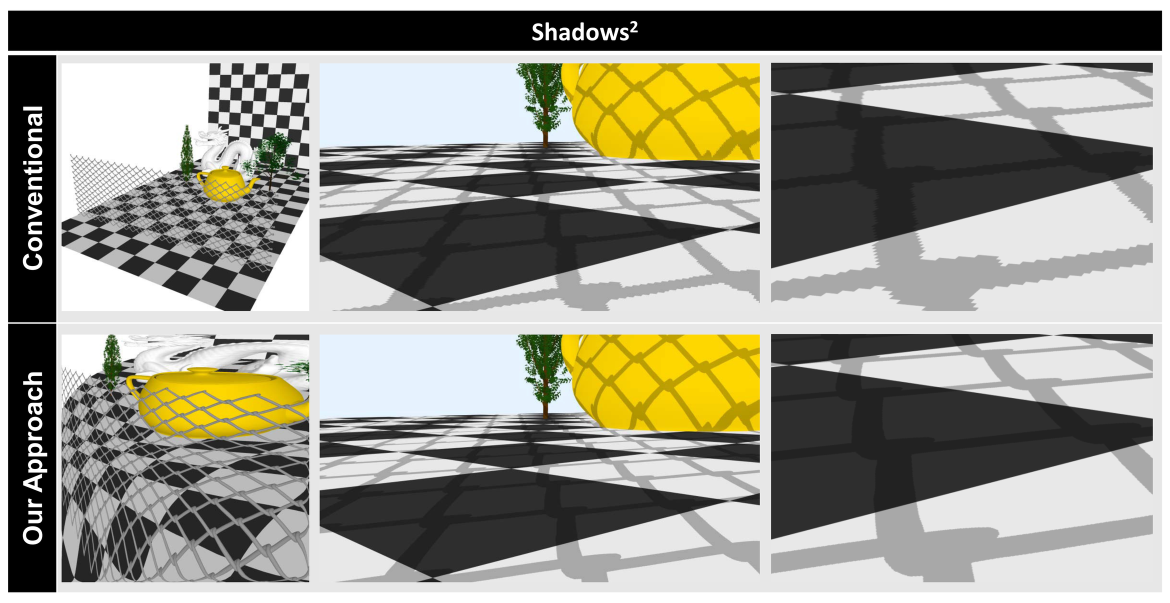


Refractions[1]



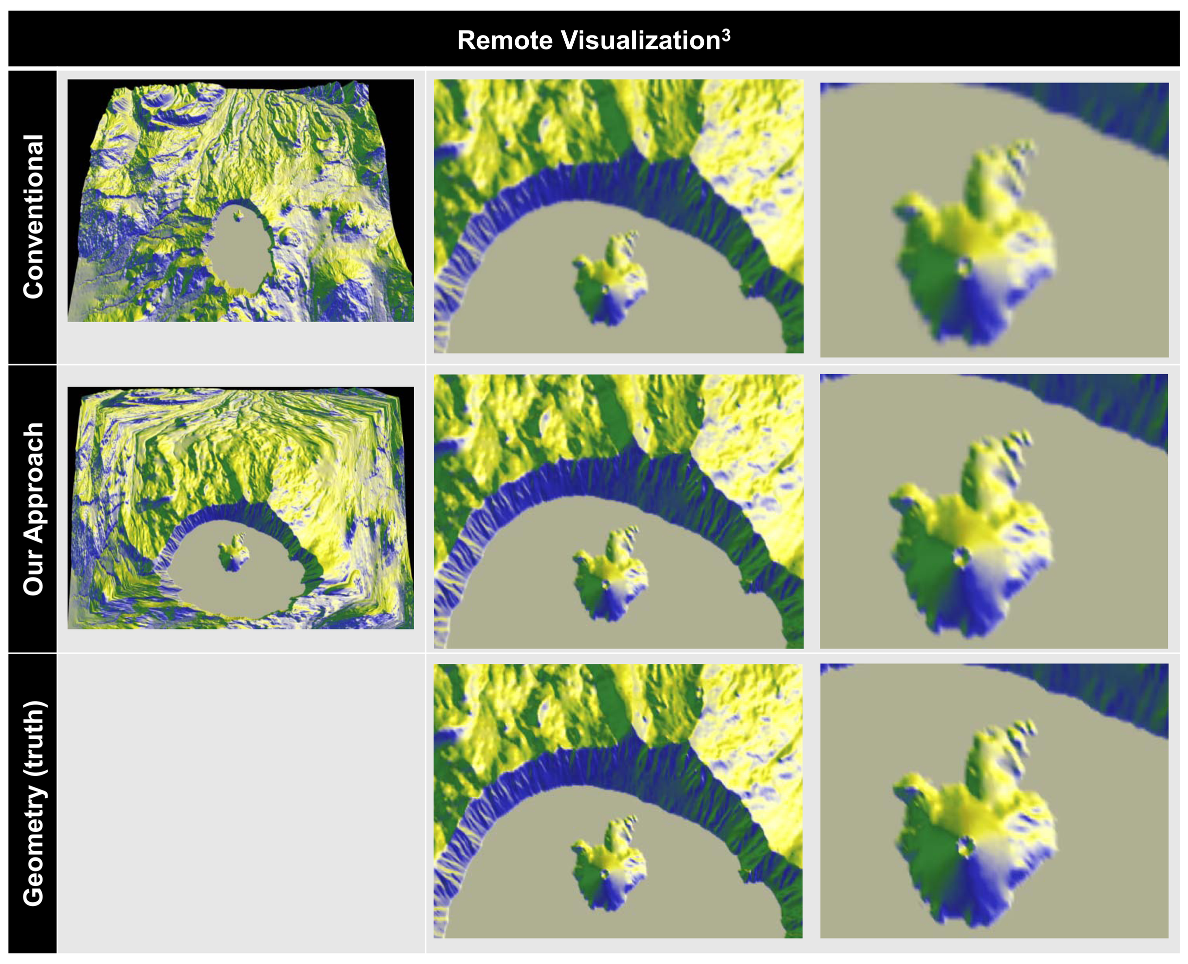
Ambient Occlusion[1]

Shadows[2]

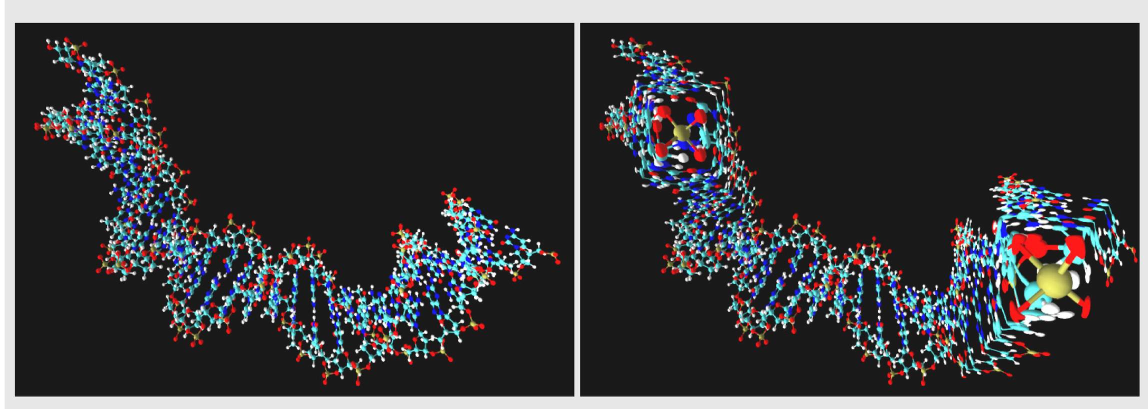


Scientific Visualization

Remote Visualization[3]



Focus Plus Context Visualization[3]



Situation Awareness

Graph Camera[4]

Centipede Panorama[5]

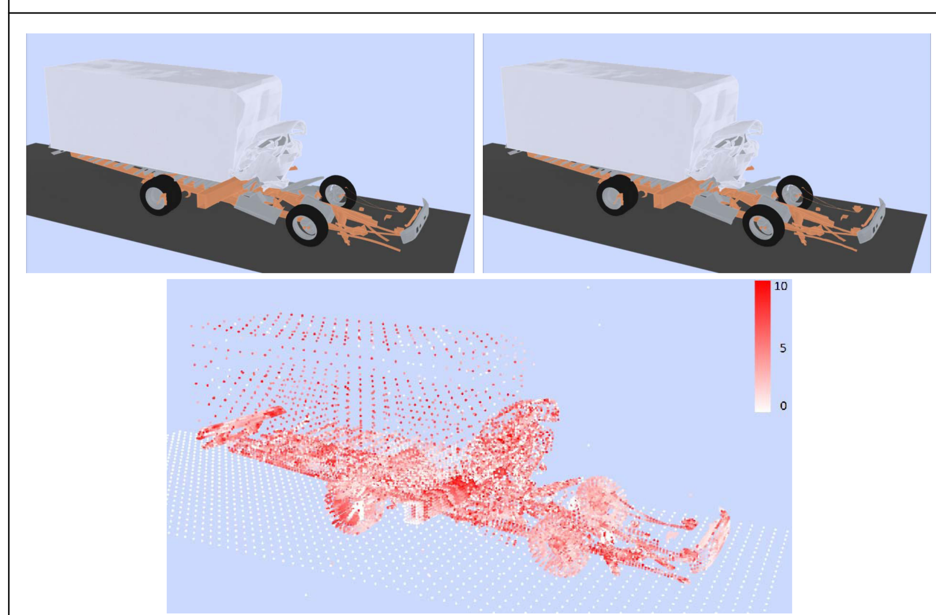
Storytelling Panorama[5]

Data Simplification for Compression and Remote Visualization of Time-Varying Datasets [6]

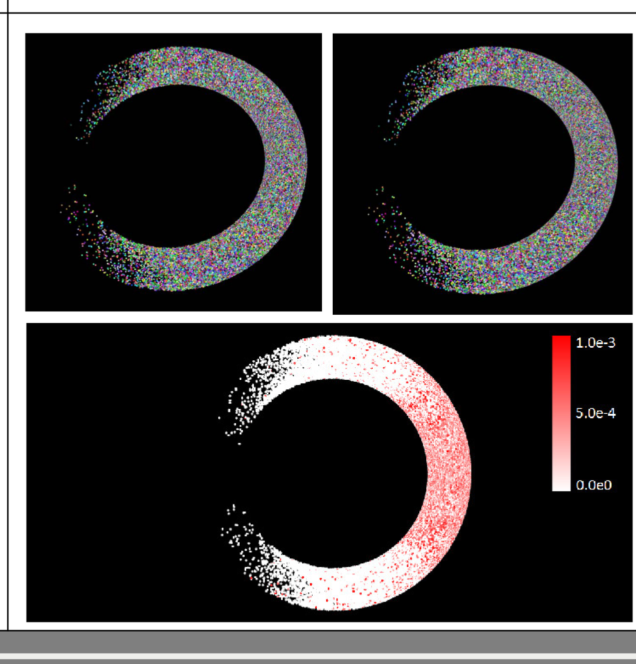
In collaboration with Voicu Popescu (Purdue University) and Seth Walsh

We propose to aid the interactive visualization of time-varying spatial datasets by simplifying node position data over the entire simulation as opposed to over individual states. Our approach is based on two observations. The first observation is that the trajectory of some nodes can be approximated well without recording the position of the node for every state. The second observation is that there are groups of nodes whose motion from one state to the next can be approximated well with a single transformation. We present dataset simplification techniques that take advantage of this node data redundancy. Our techniques are general, supporting many types of simulations, they achieve good compression factors, and they allow rigorous control of the maximum node position approximation error. We demonstrate our approach in the context of finite element analysis data, of liquid flow simulation data, and of fusion simulation data.

Truck Dataset



Fusion Dataset



Results

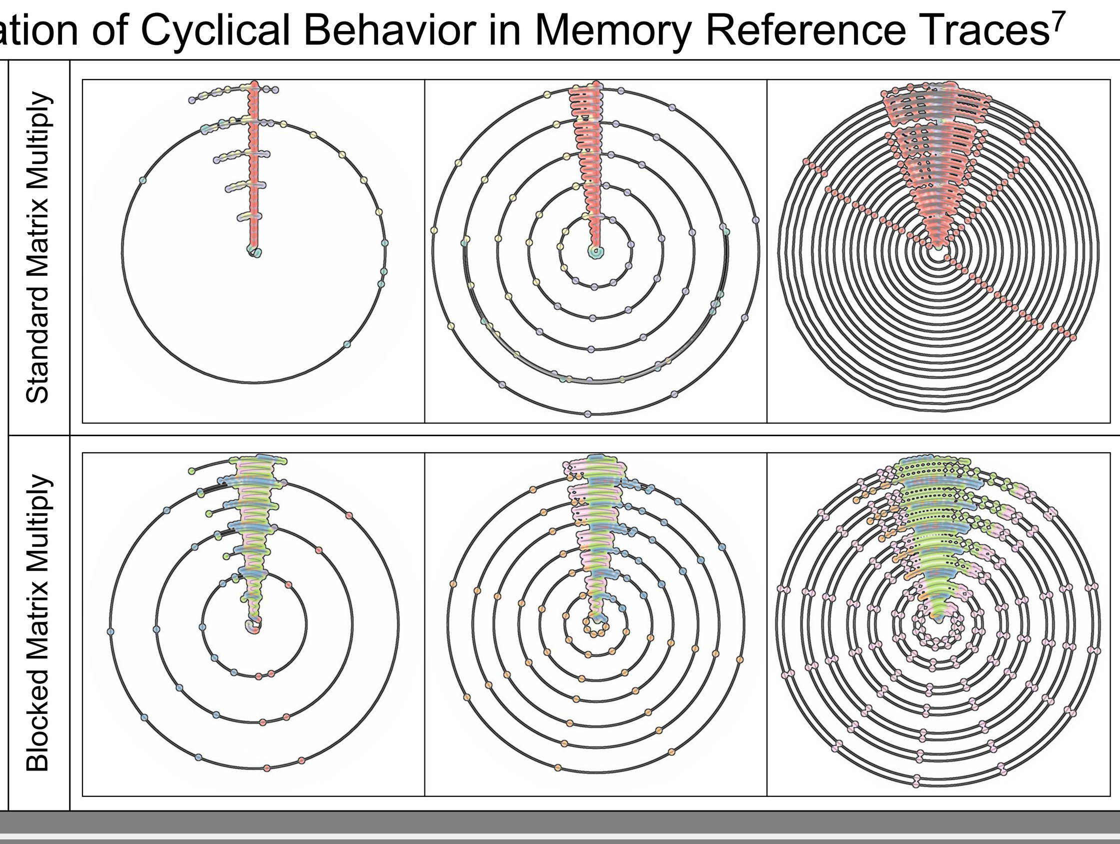
Error Threshold Absolute [mm]	Error Threshold Relative [%]	Trajectory Simplification Compression Factor	Trajectory Simplification Average Error [mm]	Trajectory Clustering Compression Factor	Trajectory Clustering Average Error [mm]	Rigidbody Decomposition Compression Factor	Rigidbody Decomposition Average Error [mm]
Truck (26.6 MB uncompressed) 15m x 5m x 3m							
1	0.0066	1.8	0.86	2.4	0.86	2.7	0.33
5	0.033	4.3	4	6.3	4.1	7.0	1.0
10	0.066	6.4	7.8	9.8	7.8	11	1.7
50	0.33	15	36	24.8	36	25	6.4
100	0.66	22	61	33.8	60	33	14
Airplane (643 MB uncompressed) 110m x 90m x 60m							
1	0.00091	4.0	0.76	4.1	0.76	4.1	0.10
5	0.0045	8.7	3.4	9.6	3.4	9.0	1.0
10	0.0091	12	6.3	14	6.3	13	2.2
50	0.045	25	25	29	25	27	11
100	0.091	34	41	39	41	38	20
Liquid (9.4 GB uncompressed) 1m x 0.18m x 0.2m							
1	0.1	7.5	0.95	12	0.94		
5	0.5	19	4.5	31	4.5		
10	1	30	8.8	47	8.8		
Fusion (4.2 GB uncompressed) 2.5m x 2.5m x 0.5m							
1	0.04	1.5	0.89	1.7	0.97		
5	0.2	3.4	4.9	3.6	4.9		
10	0.4	4.4	9.7	5	9.8		

Topological Analysis and Abstract Visualization of Software Memory Performance

In collaboration with A.N.M. Imroz Choudhury, Bei Wang, and Valerio Pascucci

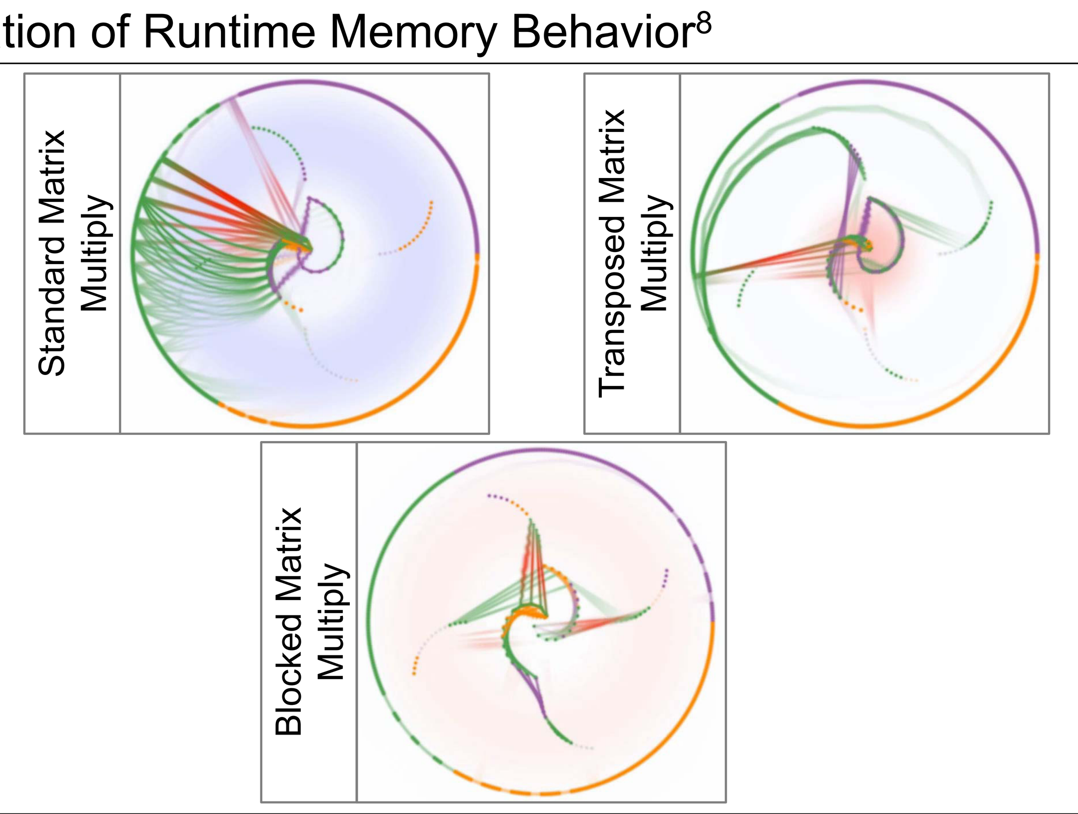
Topological Analysis and Visualization of Cyclical Behavior in Memory Reference Traces[7]

We demonstrate the application of topological analysis techniques to the rather unexpected domain of software visualization. We collect a memory reference trace from a running program, recasting the linear flow of trace records as a high-dimensional point cloud in a metric space. We use topological persistence to automatically detect circular structures in the point cloud, which represent recurrent or cyclical runtime program behaviors. We visualize such recurrences using radial plots to display their time evolution, offering multi-scale visual insights, and detecting potential candidates for memory performance optimization. We then present several case studies to demonstrate some key insights obtained using our techniques.



Abstract Visualization of Runtime Memory Behavior[8]

We present a system for visualizing memory reference traces. The visualization consists of a structured layout representing the levels of a cache and a set of data glyphs representing the pieces of data in memory. The data glyphs move in response to events generated by a cache simulator. Within the levels, the glyphs arrange themselves into shapes representing the structure of the cache levels. We make careful use of different visual channels, including structure, motion, color, and size, to convey salient events as they occur. Our visualization provides a high-level, global view of memory behavior, while giving insight about important events that may help students or software engineers to better understand their software's performance and behavior.



References

[1] P. Rosen, V. Popescu, K. Hayward, C. Wyman. **"Non-Pinhole Approximations for Interactive Rendering,"** In *IEEE Computer Graphics and Applications*, Vol. 99, 2011.

[2] P. Rosen. **"Rectilinear Texture Warping for Fast Adaptive Shadow Mapping,"** *Under review, 2011*.

[3] V. Popescu, P. Rosen, L. Arns, X. Tricoche, C. Wyman, C. Hoffmann. **"The General Pinhole Camera: Effective and Efficient Nonuniform Sampling for Visualization,"** *IEEE Transactions on Visualization and Computer Graphics*, pp. 777-790, 2010.

[4] V. Popescu, P. Rosen, N. Adamo-Villani. **"The graph camera,"** In *ACM Transactions on Graphics (Siggraph Asia 2009)*, pp. 1-8, 2009.

[5] W. Widanagamaachchi, P. Rosen, V. Pascucci. "**A Flexible Framework for Space and Time Exploring Panoramas Using Ray Graphs,"** In preparation.

[6] P. Rosen, V. Popescu. **"Simplification of Node Position Data for Interactive Visualization of Dynamic Datasets,"** In *Transactions on Computer Graphics and Visualization*, Vol. (PrePrints), 2011.

[7] A.N.M. Imroz Choudhury, B. Wang, P. Rosen, V. Pascucci, **"Topological Analysis and Visualization of Cyclical Behavior in Memory Reference Traces,"** Under review.

[8] A.N.M. Imroz Choudhury, P. Rosen. **"Abstract Visualization of Runtime Memory Behavior,"** In *6th IEEE International Workshop on Visualizing Software for Understanding and Analysis (VISSOFT 2011)*, pp. 22--29. 2011.