Cache-Oblivious Layouts of Graphs

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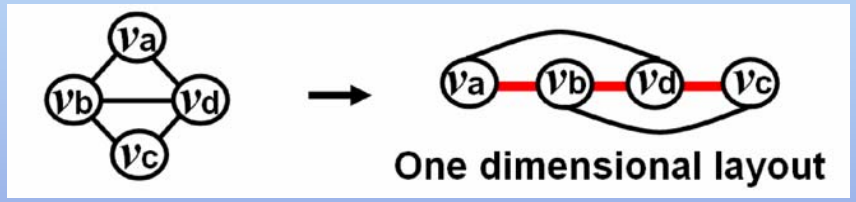
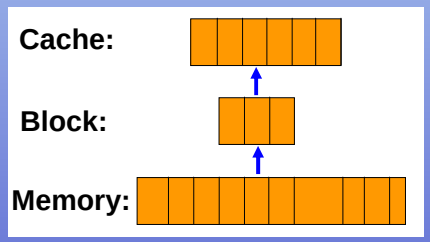
Our Goals:

- ✓ Optimization problem: Find the layout for a mesh (or a graph) that minimizes the number of cache misses for various cache parameters (e.g., cache block size)
- ✓ Derive a metric measuring the expected number of cache misses of layouts given an I/O model
- ✓ Design efficient layout algorithms for meshes based on the metric we derived



Cache-Oblivious Metric:

- ✓ The metric must reflect the number of cache misses for various cache parameters
- ✓ Two possible block size progressions (1, 2, 3, … and $2^0, 2^1, 2^2, \ldots$): obviously the second one reflects current cache architecture



Two level I/O Model

- ✓ Based on the block size assumptions, we derive two metrics: (i)arithmetic mean of edge spans - M_a and (ii)logarithm of geo--metric mean of edge spans - M_g. Experimental results show, M_g is more consistent with the actual number of cache misses

$$M_a = \frac{1}{|A|} \sum_{(i,j) \in A} l_{ij}$$

Edge span (i, j)

$$M_g = \log\left(\left(\prod_{(i,j) \in A} l_{ij} \right)^{1/|A|} \right)$$

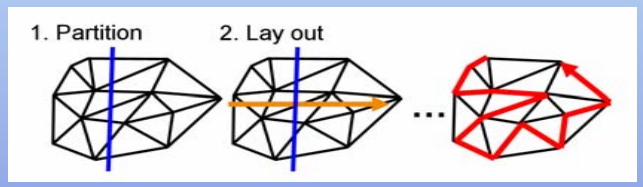
Tested block size = 4KB

Linear correlation [-1, 1]	Observed number of cache misses	
	With 1 cache block	With 5 cache blocks
M_g	0.98	0.81
M_a	-0.19	-0.32

Tested with 10 different layouts on a uniform grid

Multi-level Construction Method:

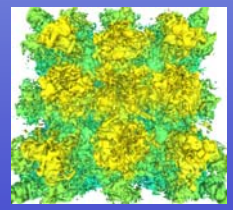
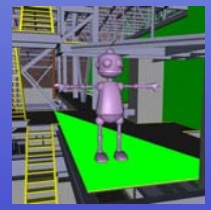
- ✓ Partition the input mesh into k different sets
- ✓ Layout partitions based on M_g



Theoretical Results:

- ✓ A random ordering of vertices gives a factor O(log n) algorithm.
- ✓ We give a constant factor algorithm for a mesh graph with the property that the maximum degree is bounded by some constant

Practical Results:


- ✓ We apply our method to triangular meshes and bounding volume hierarchies for various applications
- ✓ We are able to observe speed ups up to 5 times for GPU-based view-dependent rendering, 2 times for collision detection and ray tracing, and 10 times for iso-contour extraction method.

Related Publications:

- ✓ Mesh Layouts for Block-Based Caches, Sung-eui Yoon and Peter Lindstrom, IEEE VIS and TVCG 06
- ✓ Cache-Efficient Layouts of Bounding Volume Hierarchies, Sung-eui Yoon and Dinesh Manocha, Eurographics 06
- ✓ Cache-Oblivious Mesh Layouts, S.E. Yoon, P. Lindstrom, V. Pascucci, and D. Manocha, SIGGRAPH 05