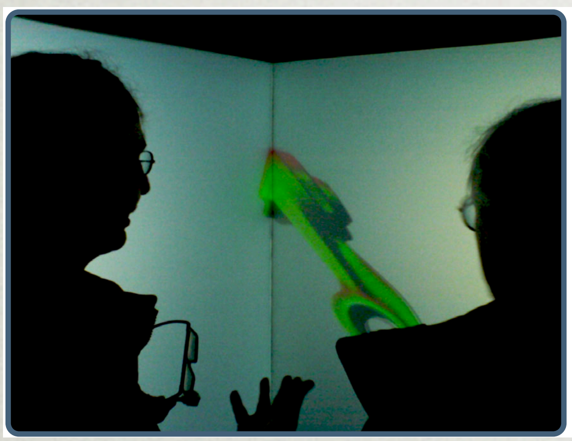
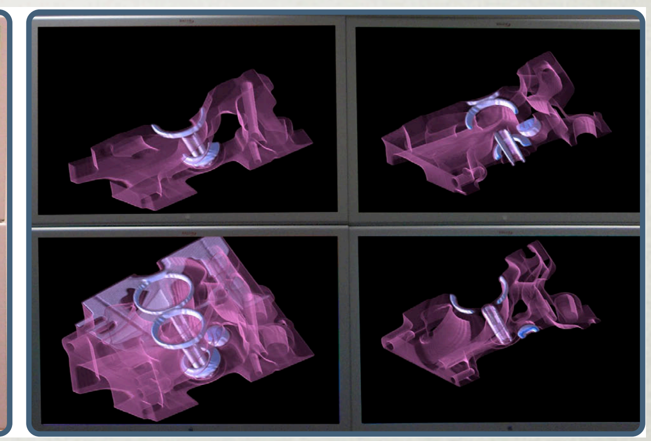
Parallel Rendering

with Equalizer





Prof. Dr. Renato Pajarola

wissen teilen
175 jahre universität zürich

University of Zurich
Department of Informatics

VMML
visualization and multimedia lab
university of zürich

Outline

- Motivation
- Parallel Rendering
- Multipipe System
- Equalizer

VMML
visualization and multimedia lab
university of zürich

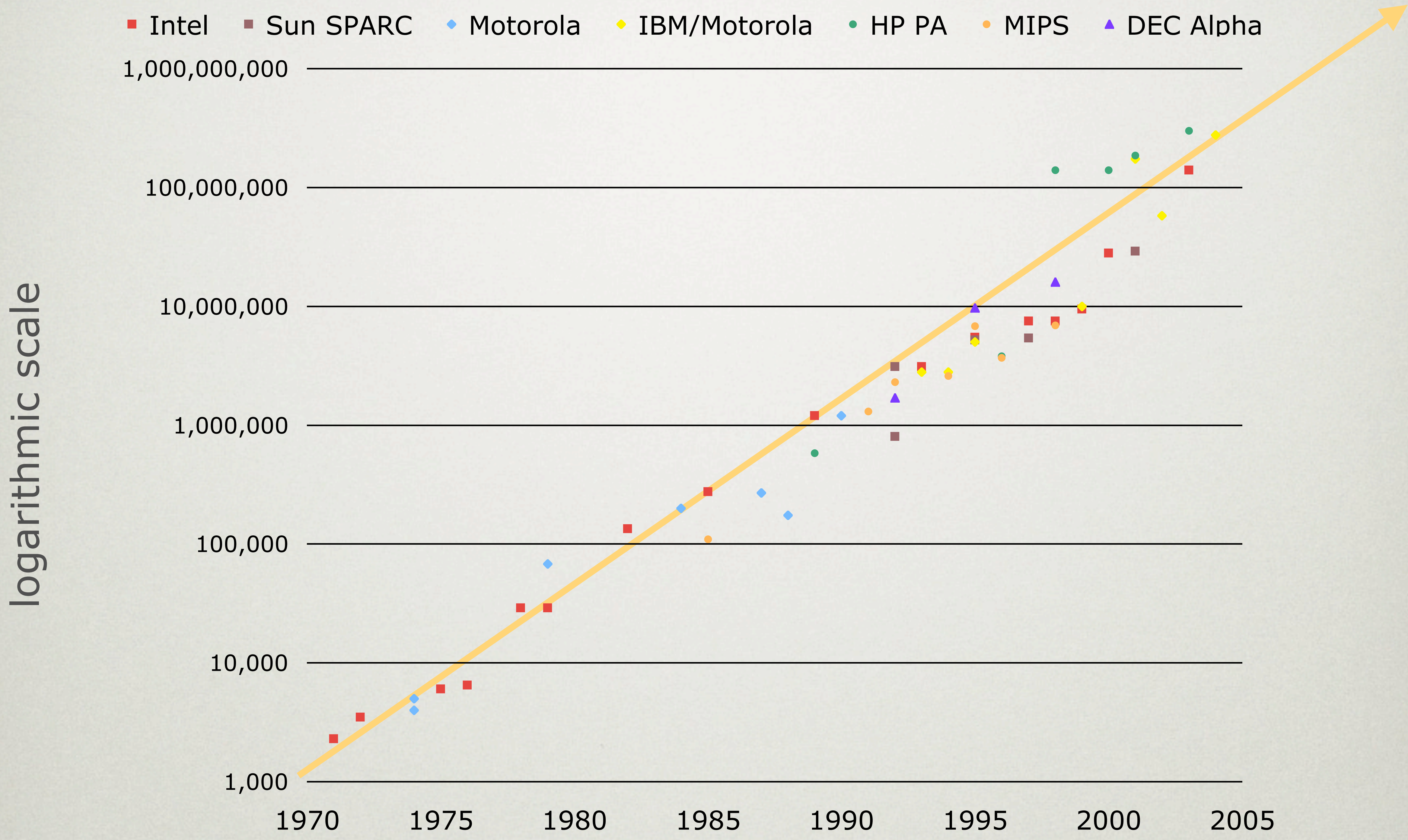
Massive Data Visualization

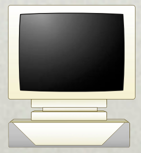
- Processing and rendering requirements exceeding available computing resources
  - Memory
    - data size larger than available physical main memory
  - CPU/GPU
    - bandwidth limited to process data *interactively*
  - Display
    - too many elements to see and display

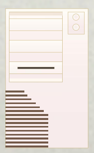
Why is large a problem?

- Moore's law
  + Computing power doubles every 18 months
    - improvement of hardware will cope with any conceivable data sets in foreseeable future
- But...
  - Data is generated by same hardware
    - same growth can be expected
  - Interactivity

CPU Performance (transistor count)

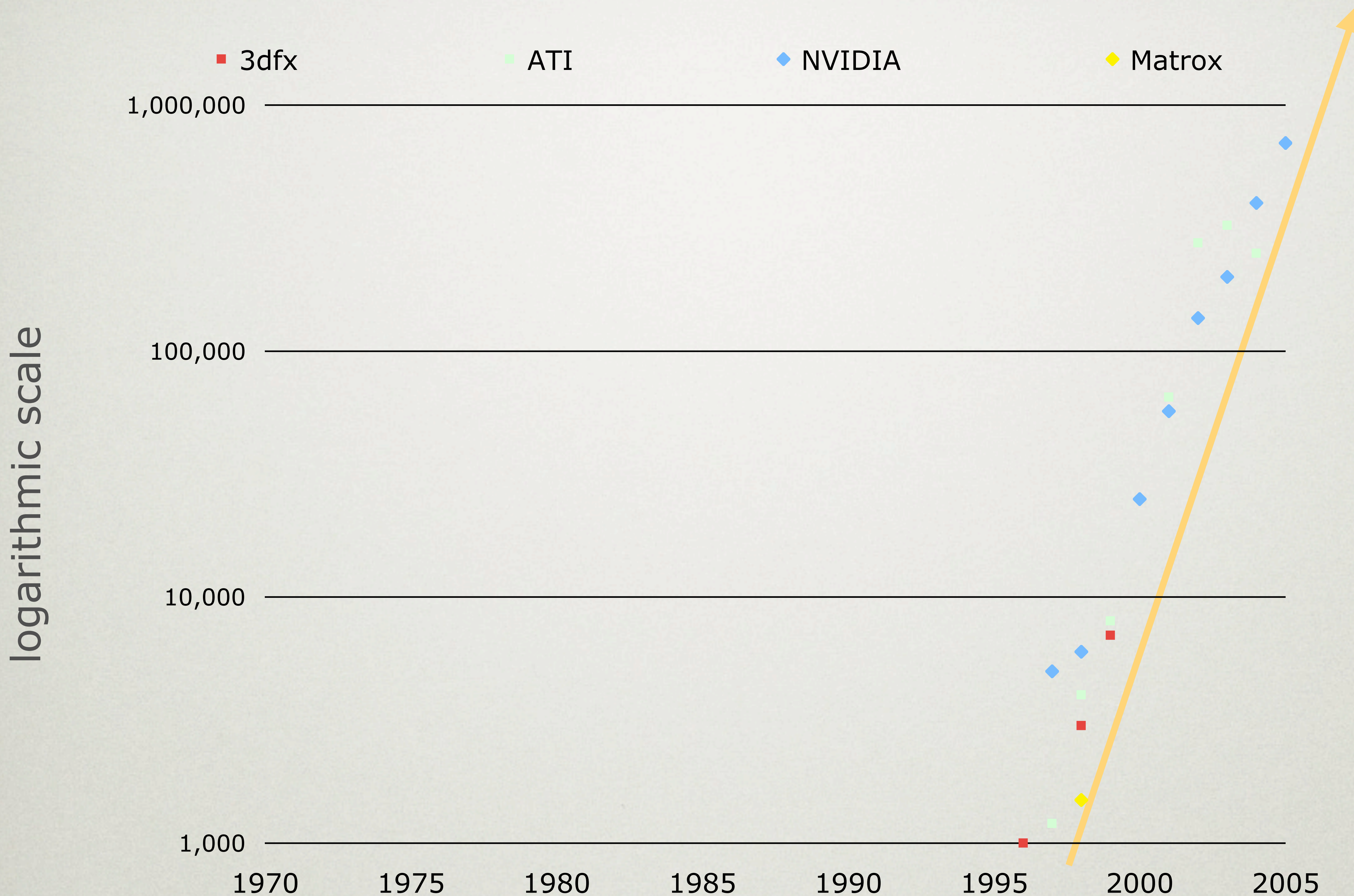


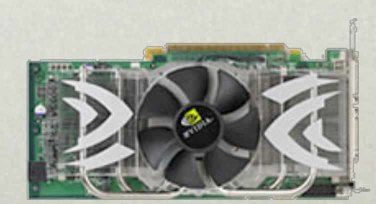




VMML
visualization and multimedia lab
university of zürich

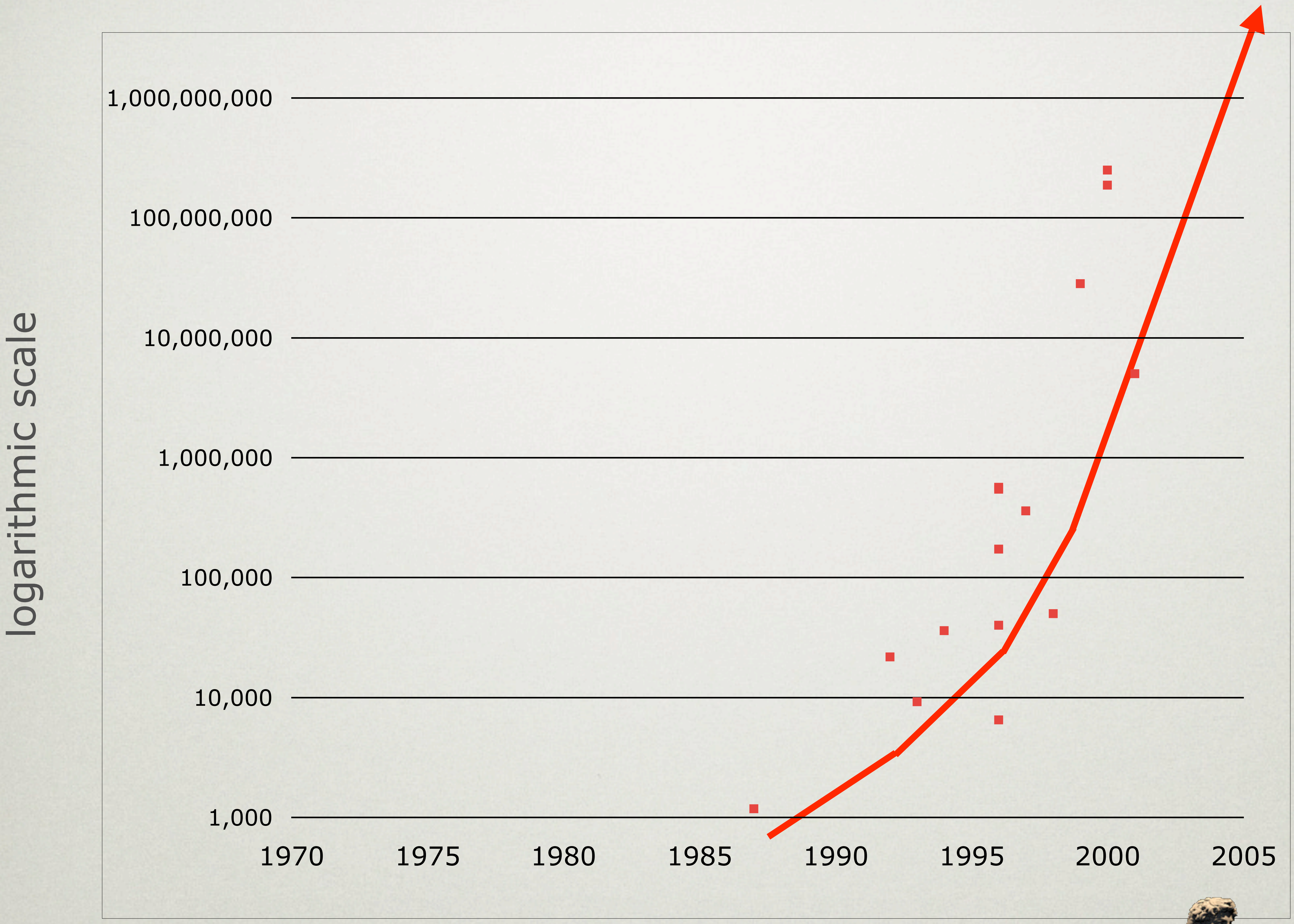
GPU Performance (triangles/sec)





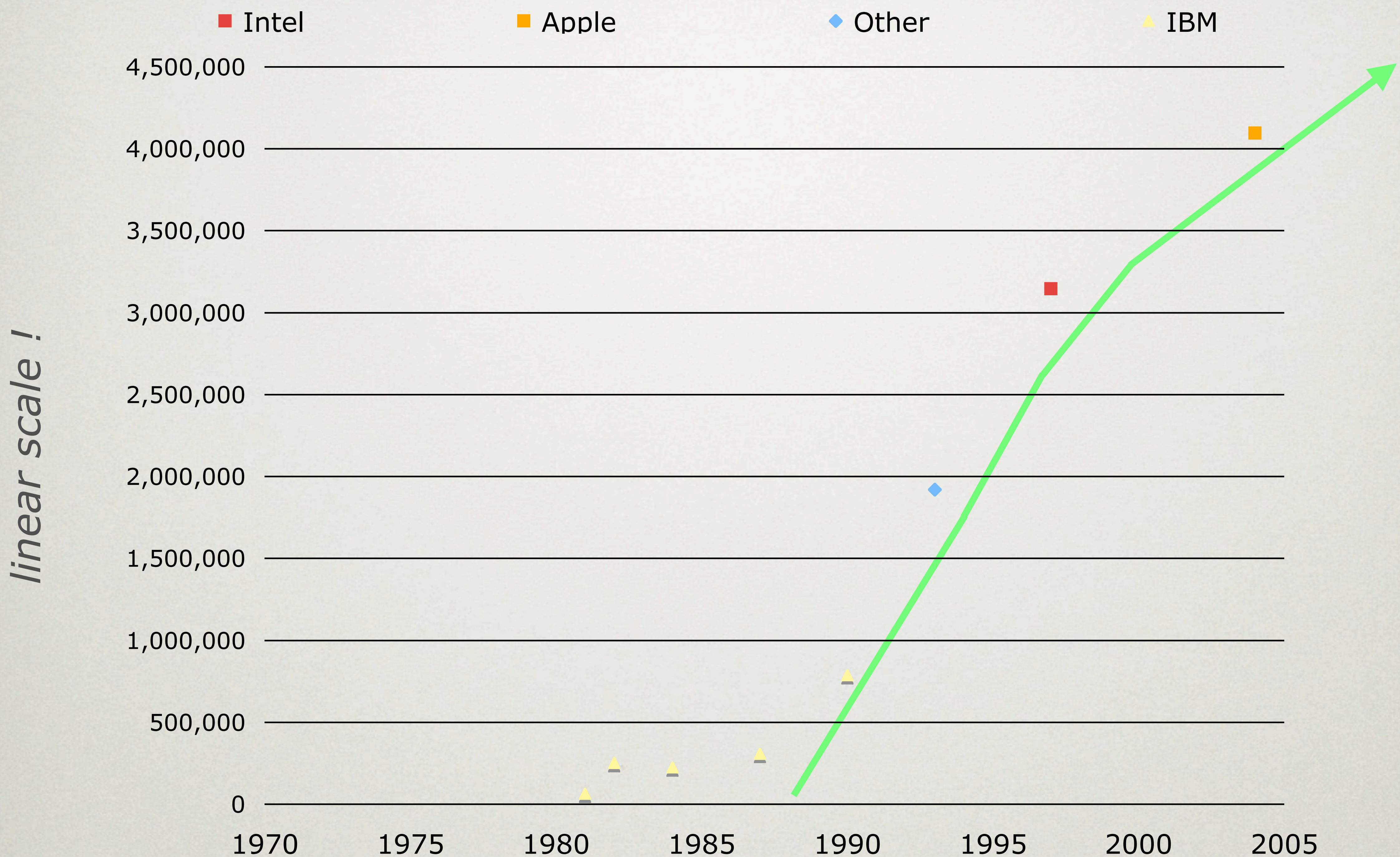
VMML
visualization and multimedia lab
university of zürich

3D Model Sizes (number of vertices)



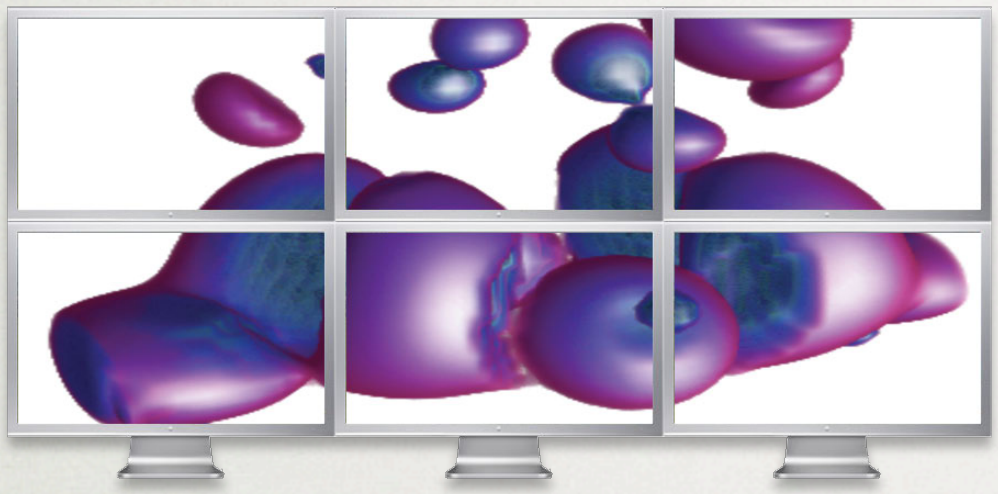
VMML
visualization and multimedia lab
university of zürich

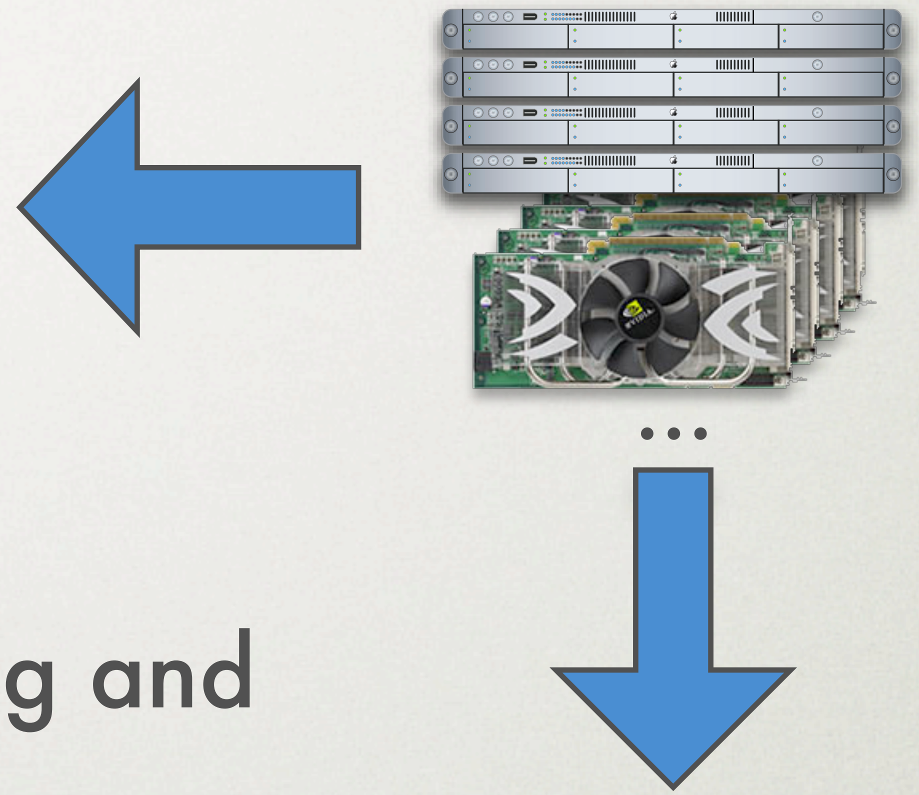
Display Resolution (pixels on display)



VMML
visualization and multimedia lab
university of zürich

Parallel Hardware





- Exploit parallel computing and rendering resources
    - parallel cluster computer
    - multi-GPU acceleration
    - high-speed interconnect

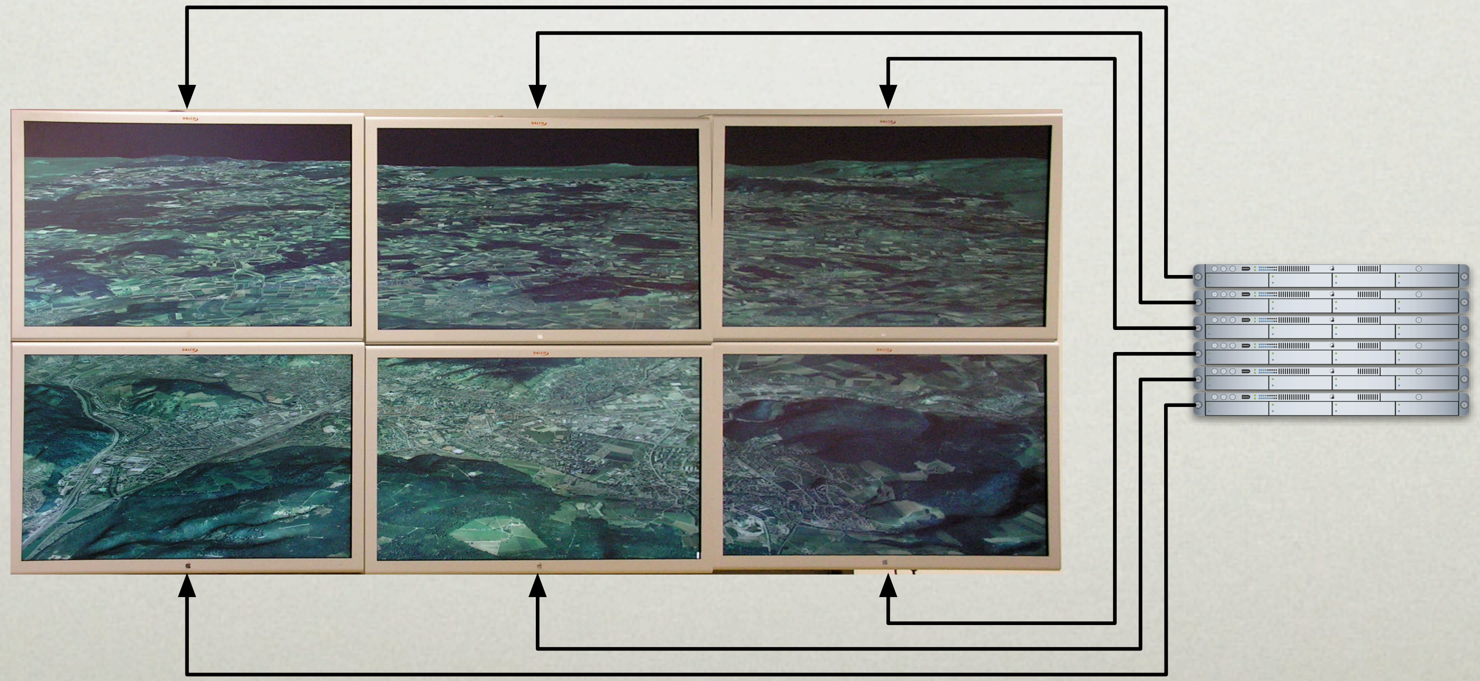
VMML
visualization and multimedia lab
university of zürich

Application Environments

- Display Walls
- Virtual Reality
- Remote Rendering
- Parallel Rendering

Display Walls

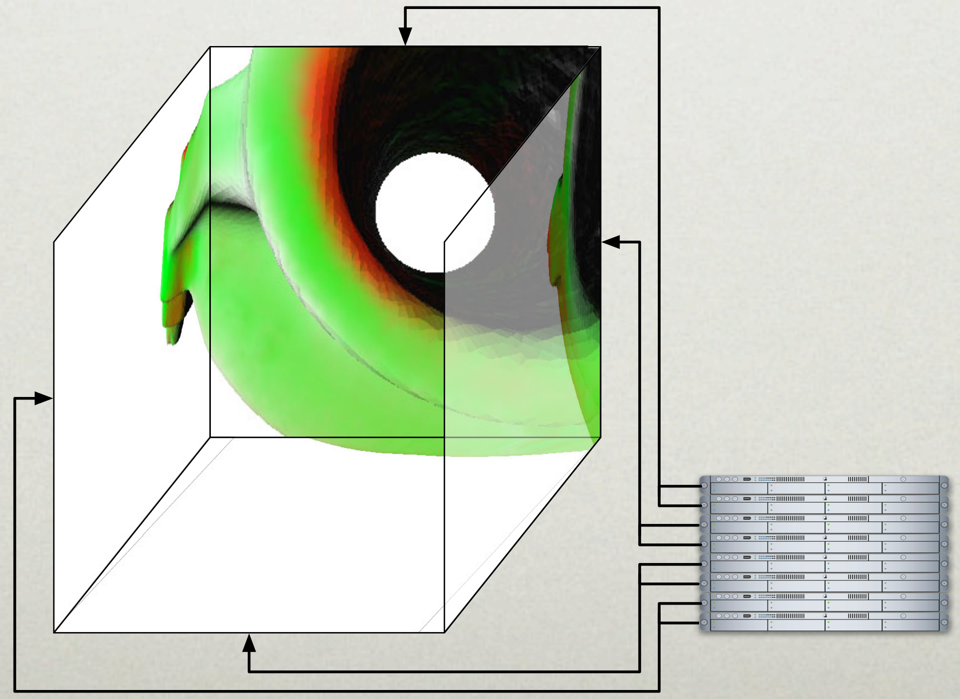
- Group collaboration
- Better data understanding
- One or more displays per computer
- High resolution: 10-100 MPixels



VMML
visualization and multimedia lab
university of zürich

Virtual Reality

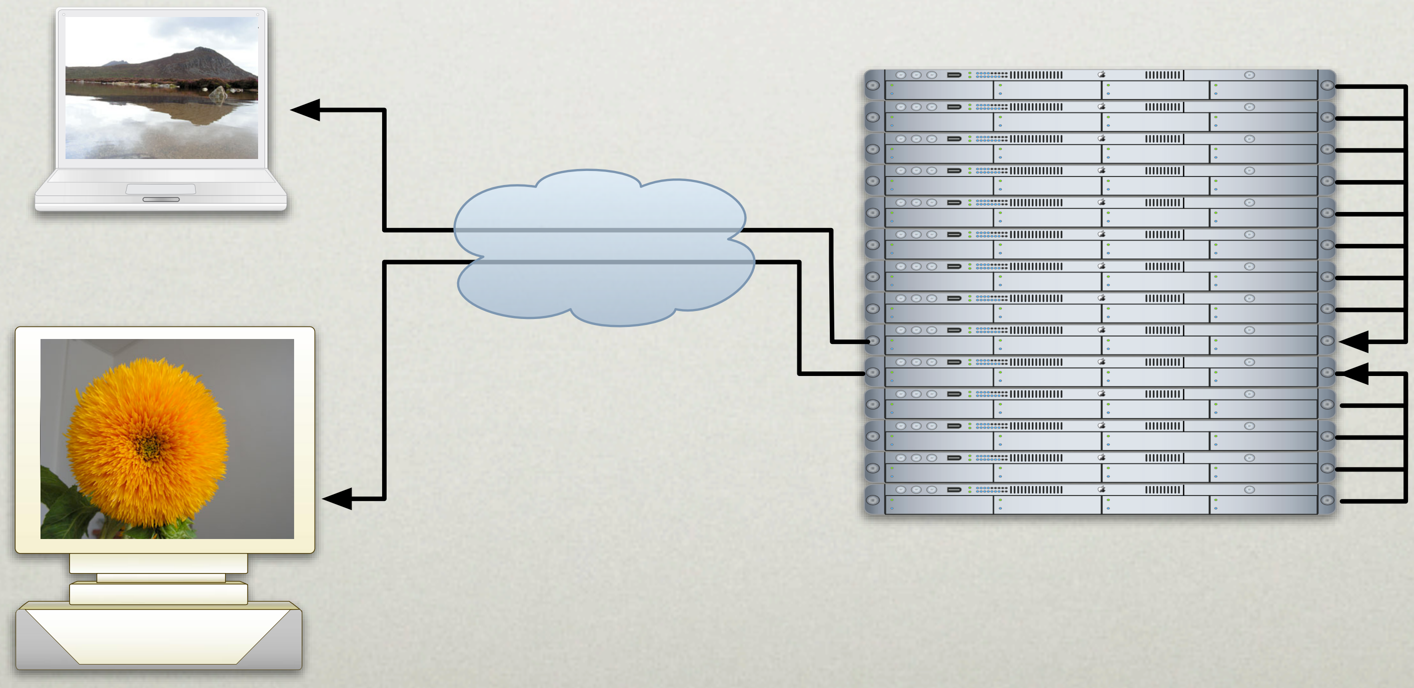
- Stereo rendering, head tracking
- Immersive displays with high frame rates
- CAVEs with up to two computers per wall with passive stereo



VMML
visualization and multimedia lab
university of zürich

Remote Rendering

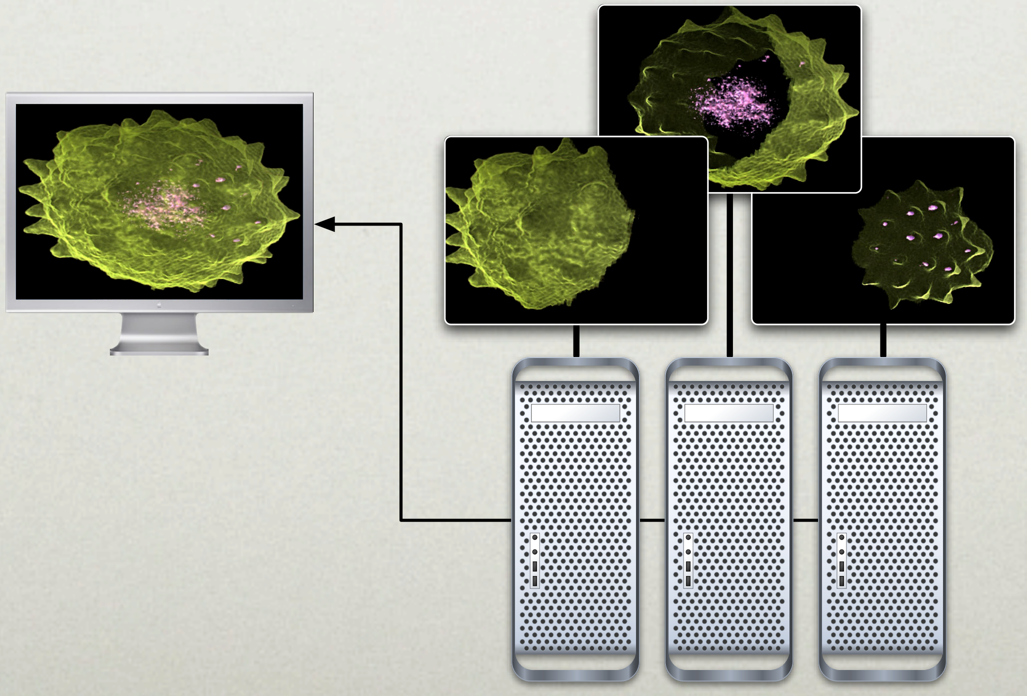
- Centralize data, software and hardware
- Combined with scalable rendering
- Avoids copying of HPC result data
- Simplifies administration



VMML
visualization and multimedia lab
university of zürich

Scalable Rendering

- Render massive data sets interactively
- Exploit multiple graphics cards (GPUs) and processors (CPUs) per display
- Different algorithms for parallelization



VMML
visualization and multimedia lab
university of zürich

Outline

- Motivation
- Parallel Rendering
- Multipipe System
- Equalizer

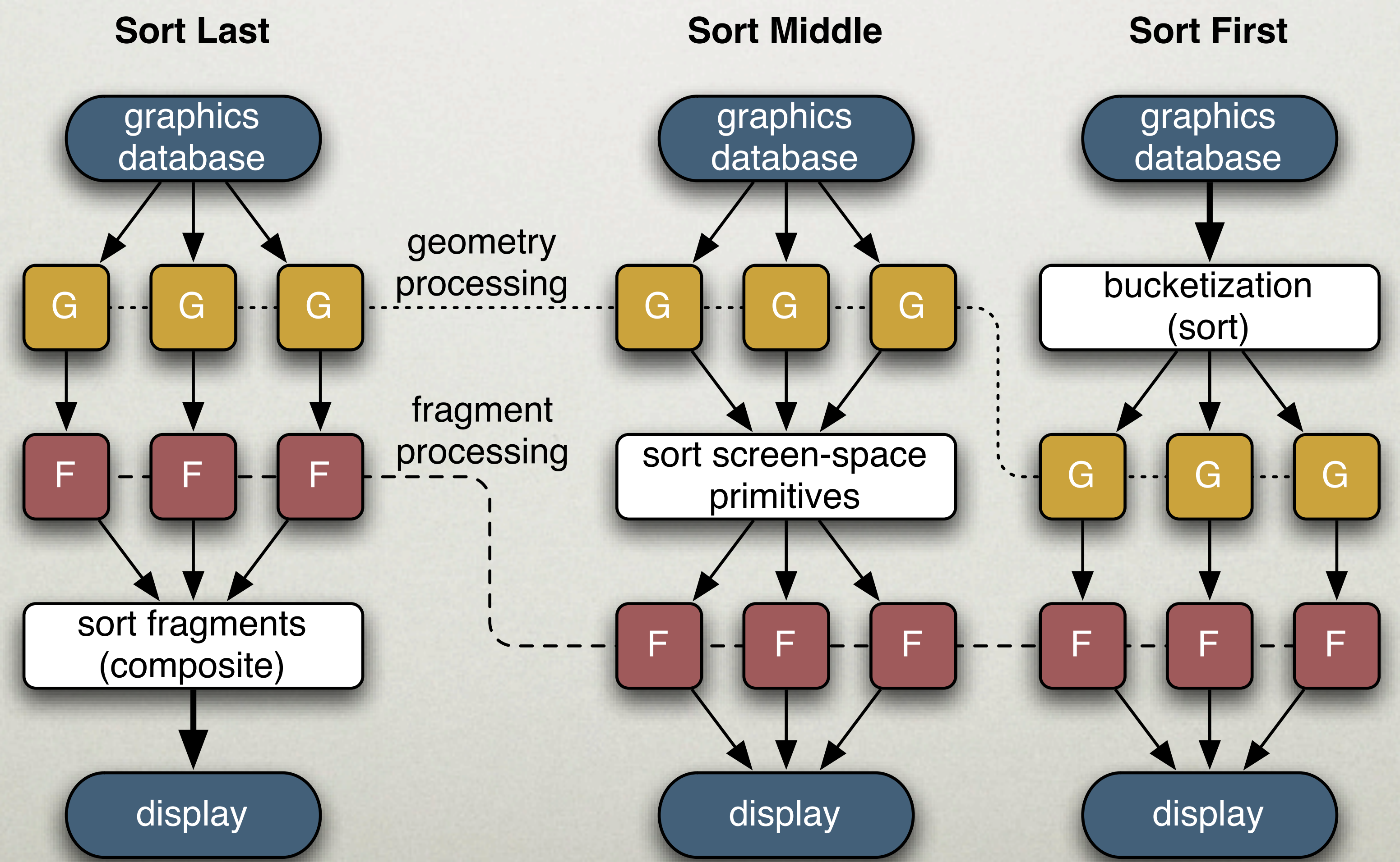
VMML
visualization and multimedia lab
university of zürich

Rendering Task Decomposition

- Single frame decomposition
  - **sort-first**: screen-space decomposition
  - **sort-middle**: only practical on GPU
  - **sort-last**: database decomposition
- Entire frame decomposition
  - **DPlex**: time-multiplex
  - **Eye**: stereo passes

Rendering Pipeline

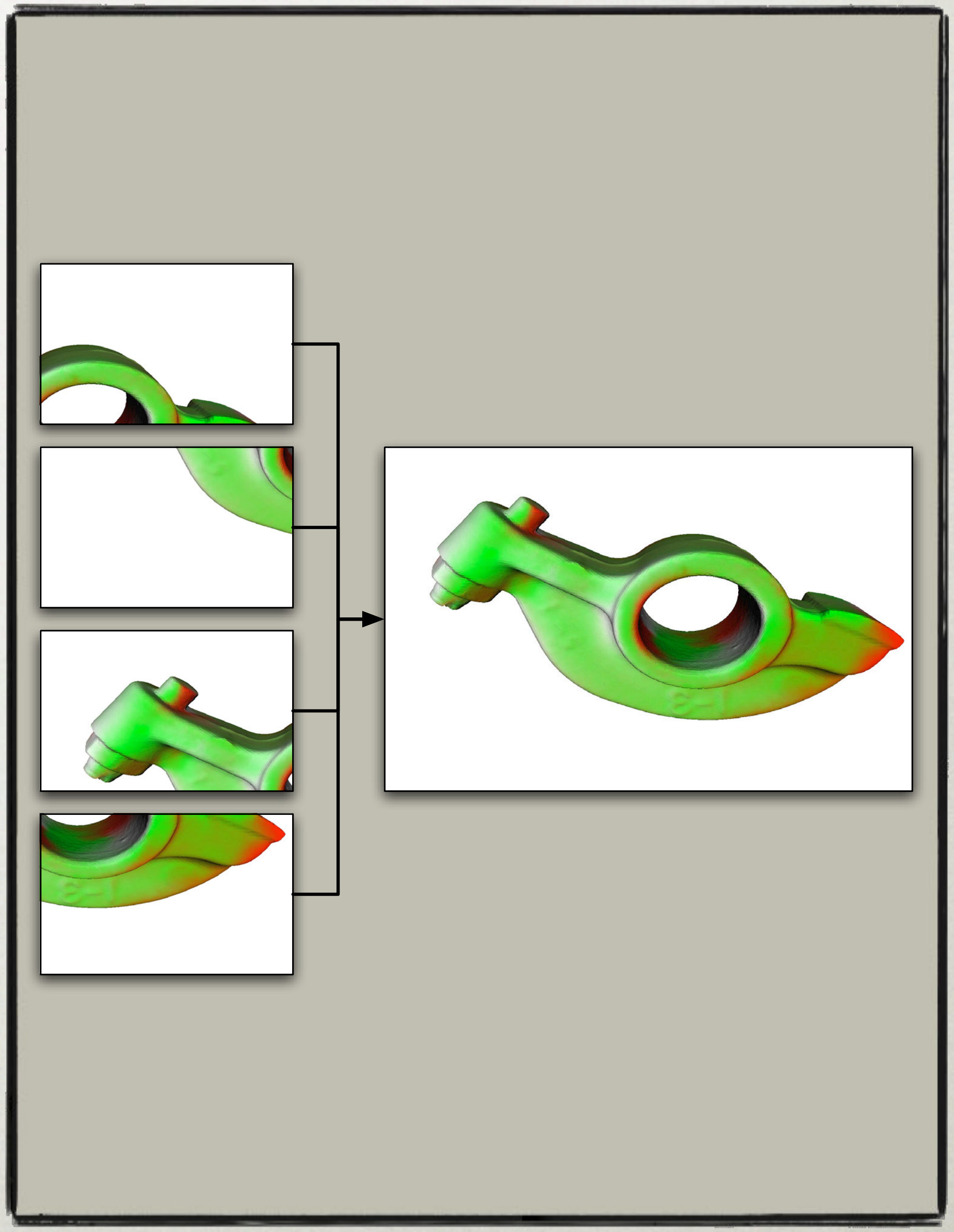
1. Transform geometry into screen space
2. Rasterize primitives into fragments
3. Process fragments into pixels



VMML
visualization and multimedia lab
university of zürich

2D/Sort-First

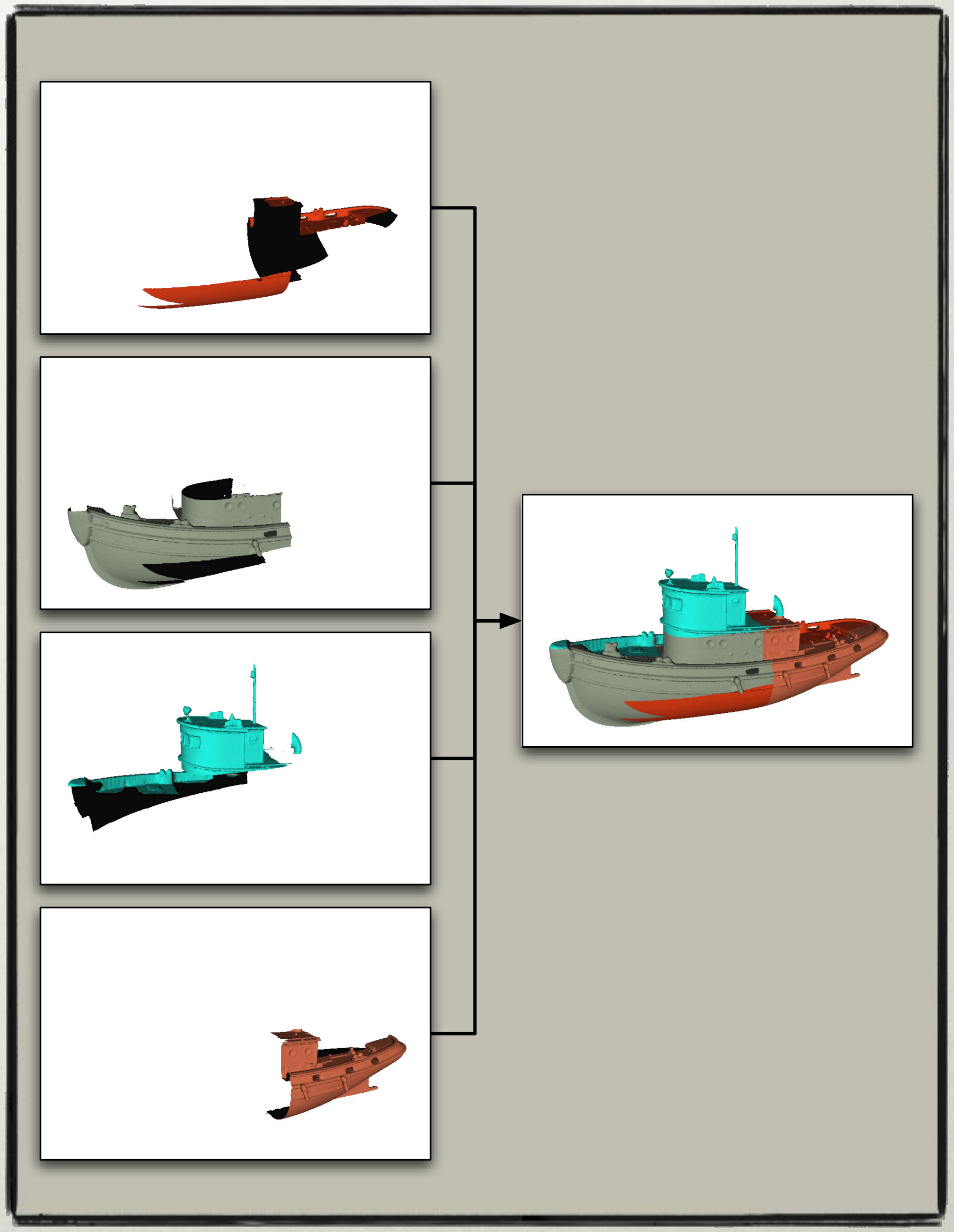
- Scales fillrate/fragment processing
- Scales geometry with efficient view frustum culling
- Parallel overhead due to primitive overlap limits scalability



VMML
visualization and multimedia lab
university of zürich

DB/Sort-Last

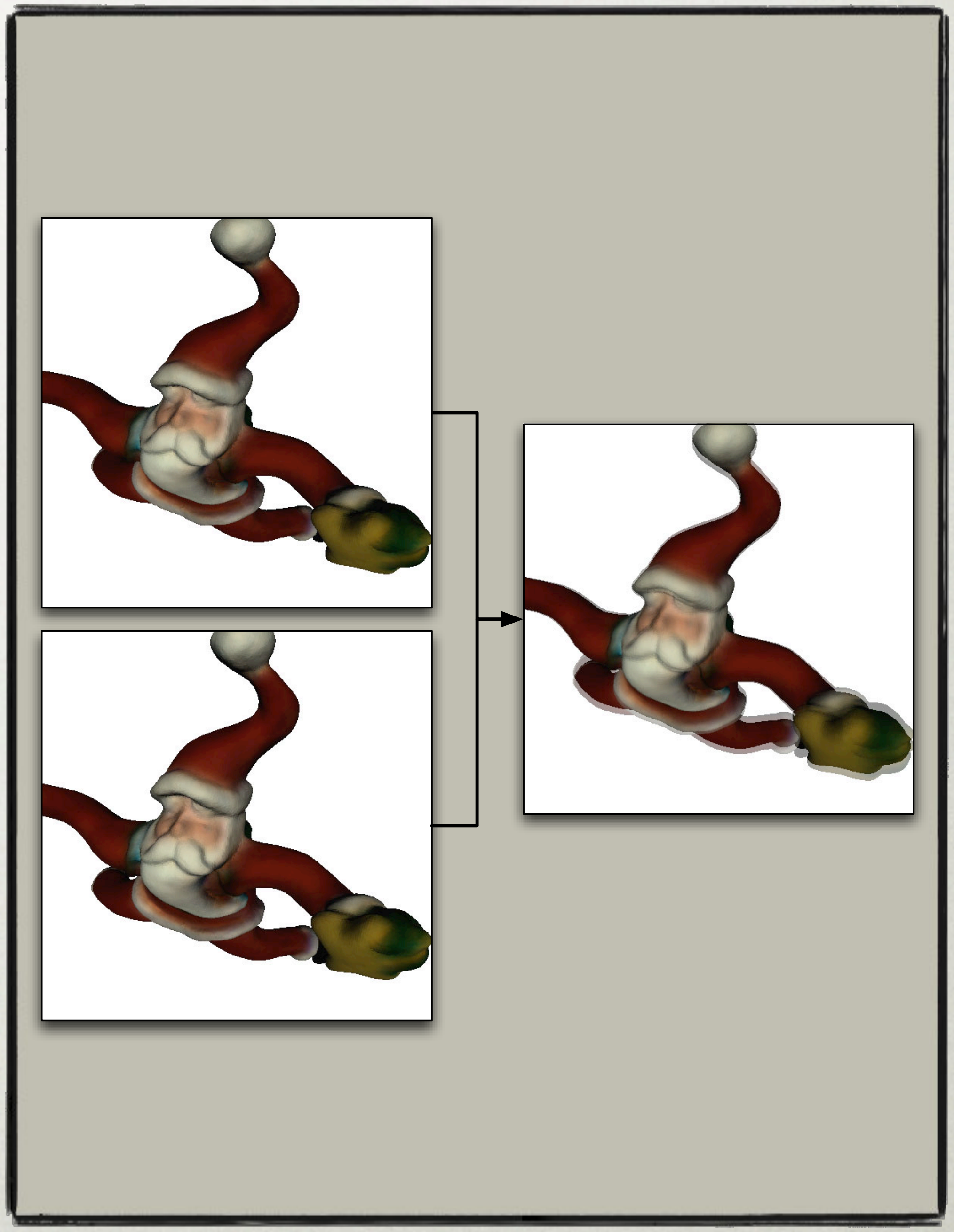
- Scales all aspects of rendering pipeline
- Application needs to be adapted to render subrange of data
- Recomposition relatively expensive



VMML
visualization and multimedia lab
university of zürich

Eye/Stereo

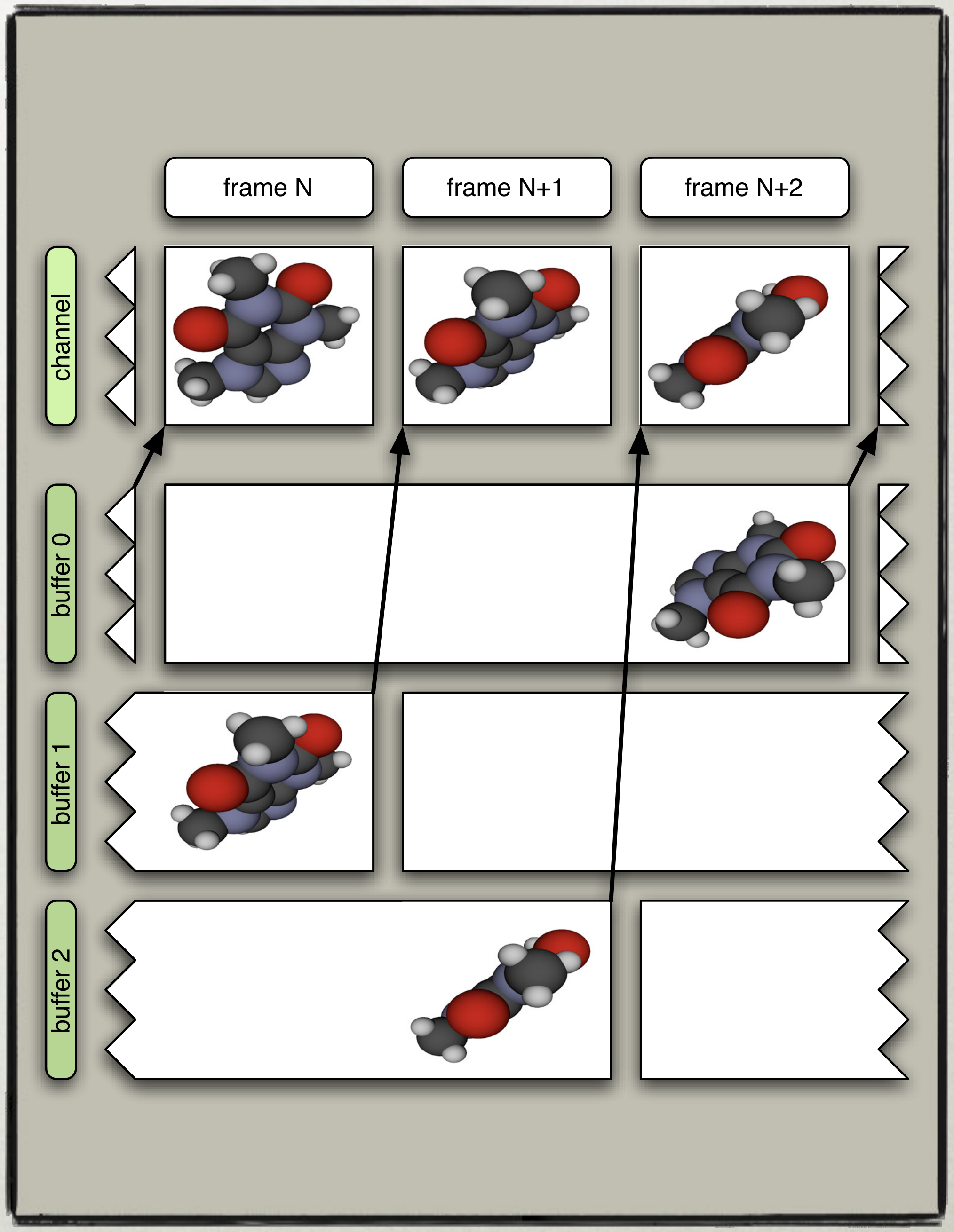
- Stereo rendering
- Excellent load balancing
- Limited by number of eye views



visualization and multimedia lab
university of zürich

DPlex/Time-Multiplex

- Good scalability and load balancing
- Increased latency may not be acceptable



VMML
visualization and multimedia lab
university of zürich

Conclusion

- No 'magic bullet'
- 2D is ideal for less than eight pipes
- Use Eye if running in stereo
- DB scales well

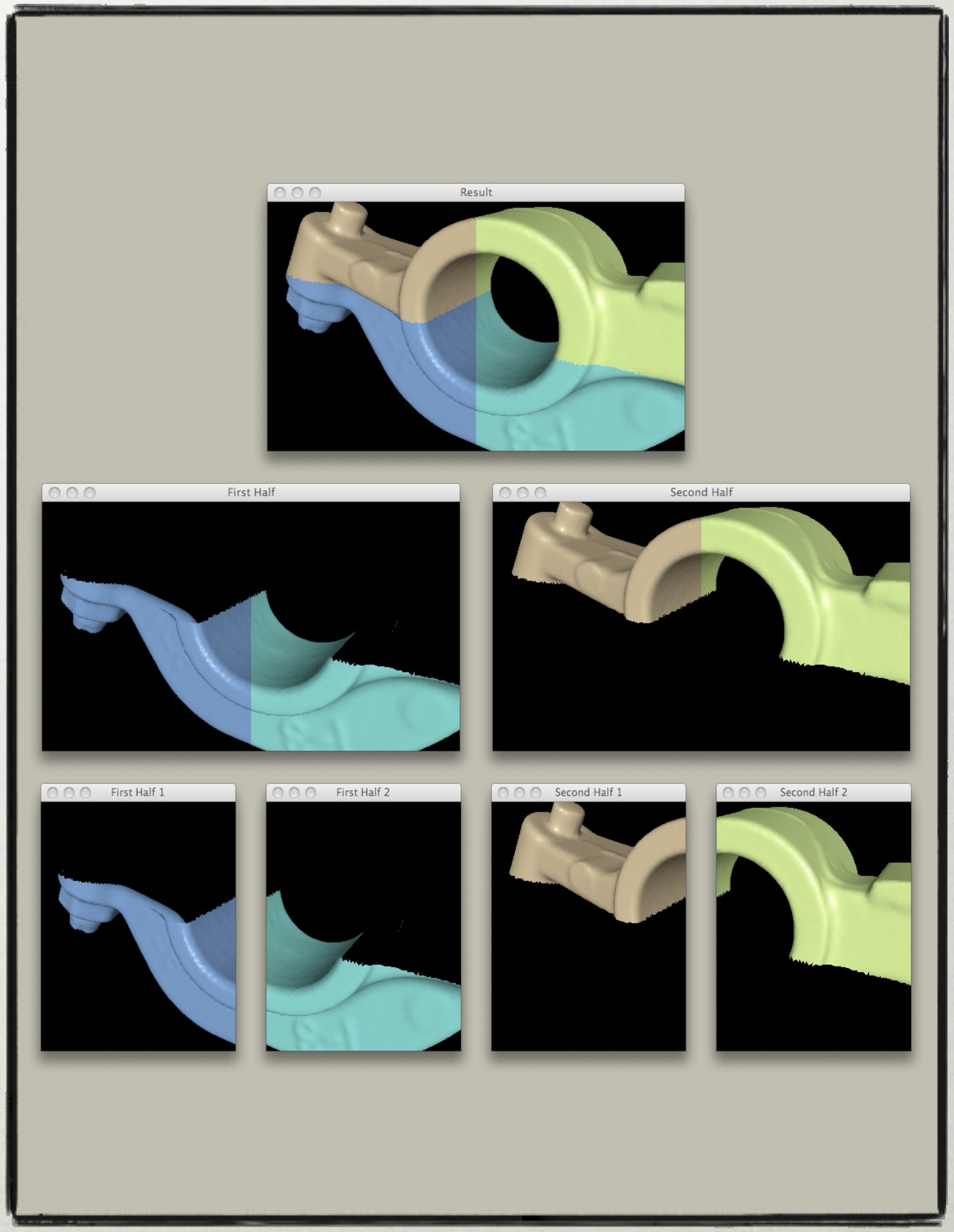
➡ Combine modes

	2D	DB	DPlex	Eye
Fillrate	++	+	++	++
Vertex Processing	0	++	++	++
Memory Usage	0	++	0	0
Load Balancing	0	+	++	++
Latency	++	++	-	++
Re-assembly	+	-	+	+

VMML
visualization and multimedia lab
university of zürich

Equalizer Multilevel Compounds

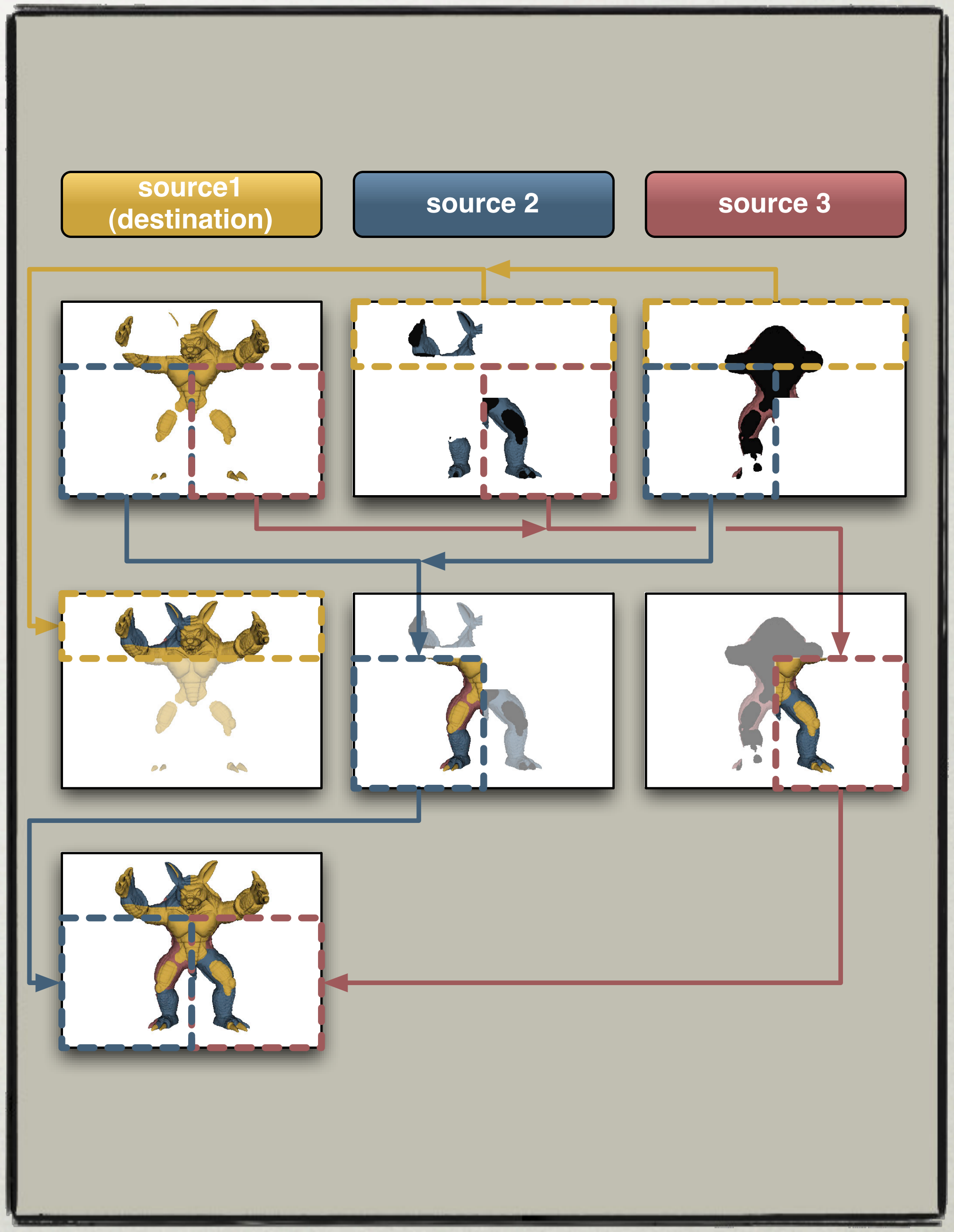
- Compounds allow any combination of modes
- Combine different algorithm to address and balance bottlenecks
- Example: use DB to fit data on GPU, then use 2D to scale further



VMML
visualization and multimedia lab
university of zürich

Parallel Compositing

- Compositing cost grows linearly for DB
- Parallelize compositing
- Flexible configuration
- Constant per-node cost
- Details in EGPGV'07 paper



VMML
visualization and multimedia lab
university of zürich

Outline

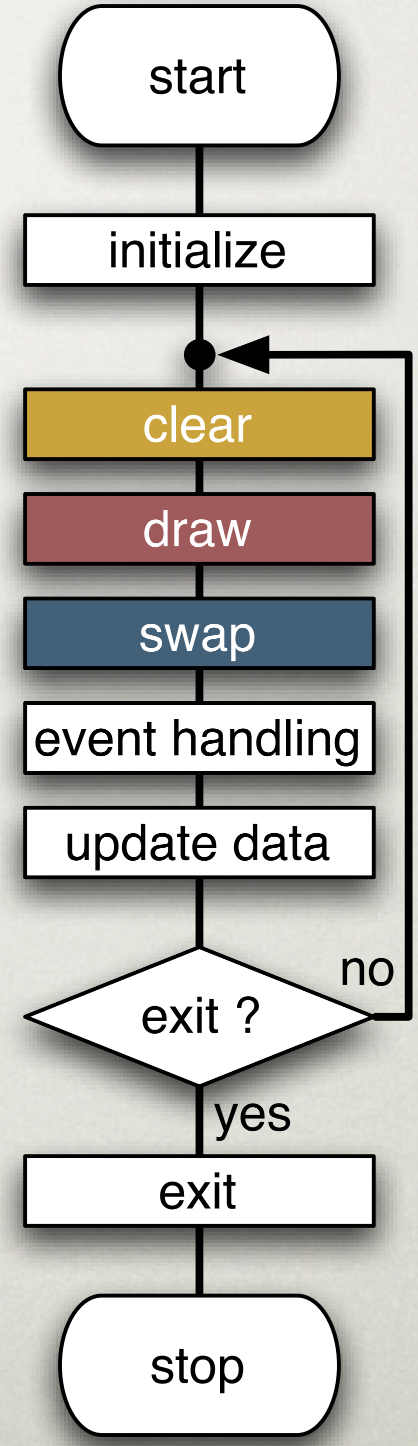
- Motivation
- Parallel Rendering
- Multipipe System
- Equalizer

Parallel Applications

- Single pipe application
  - traditional application and rendering model
- Multipipe application
  - multiple instances of software run on different nodes and interact

Single Pipe Rendering

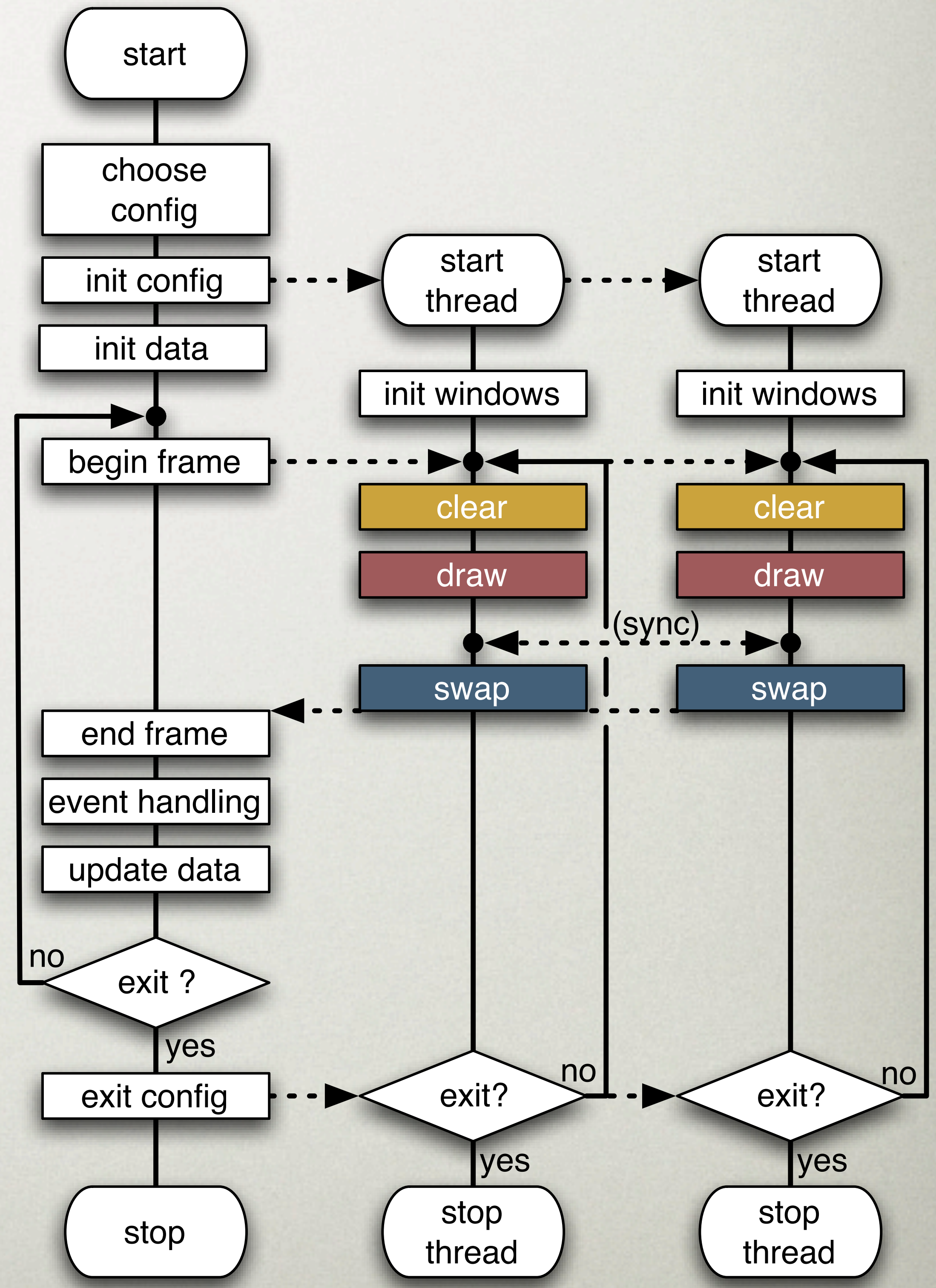
- Typical rendering loop
- Stages may not be well separated



VMML
visualization and multimedia lab
university of zürich

Multipipe Rendering

- Equalizer separates rendering and application
- Instantiate rendering multiple times
- Synchronize parallel execution



Runtime Scalability

- Parallel execution of the application's rendering code
- One thread per graphics card, one process per node
- Decomposition of rendering for one view

VMML
visualization and multimedia lab
university of zürich

Asynchronous Execution

- A rendering thread (channel) can start rendering the next frame early
  - hides imbalance in load distribution
  - only visible channels belonging to the same view are synchronized
- Greatly improves scalability on bigger clusters

VMML
visualization and multimedia lab
university of zürich

Outline

- Motivation
- Parallel Rendering
- Multipipe System
- Equalizer

Equalizer Concepts

"GLUT for multi-GPU systems and visualization clusters"

- **Task-driven**: init, exit, clear, draw, (readback, assemble)
- **Resource-based**: Node, Pipe, Window, Channel

Equalizer API

Parallel rendering applications are written against a *client library* which abstracts the interface to the execution environment

➡ Library and API

- Minimally invasive programming approach
- Abstracts multi-processing, synchronization and data transport
- Supports distributed rendering and performs frame compositing

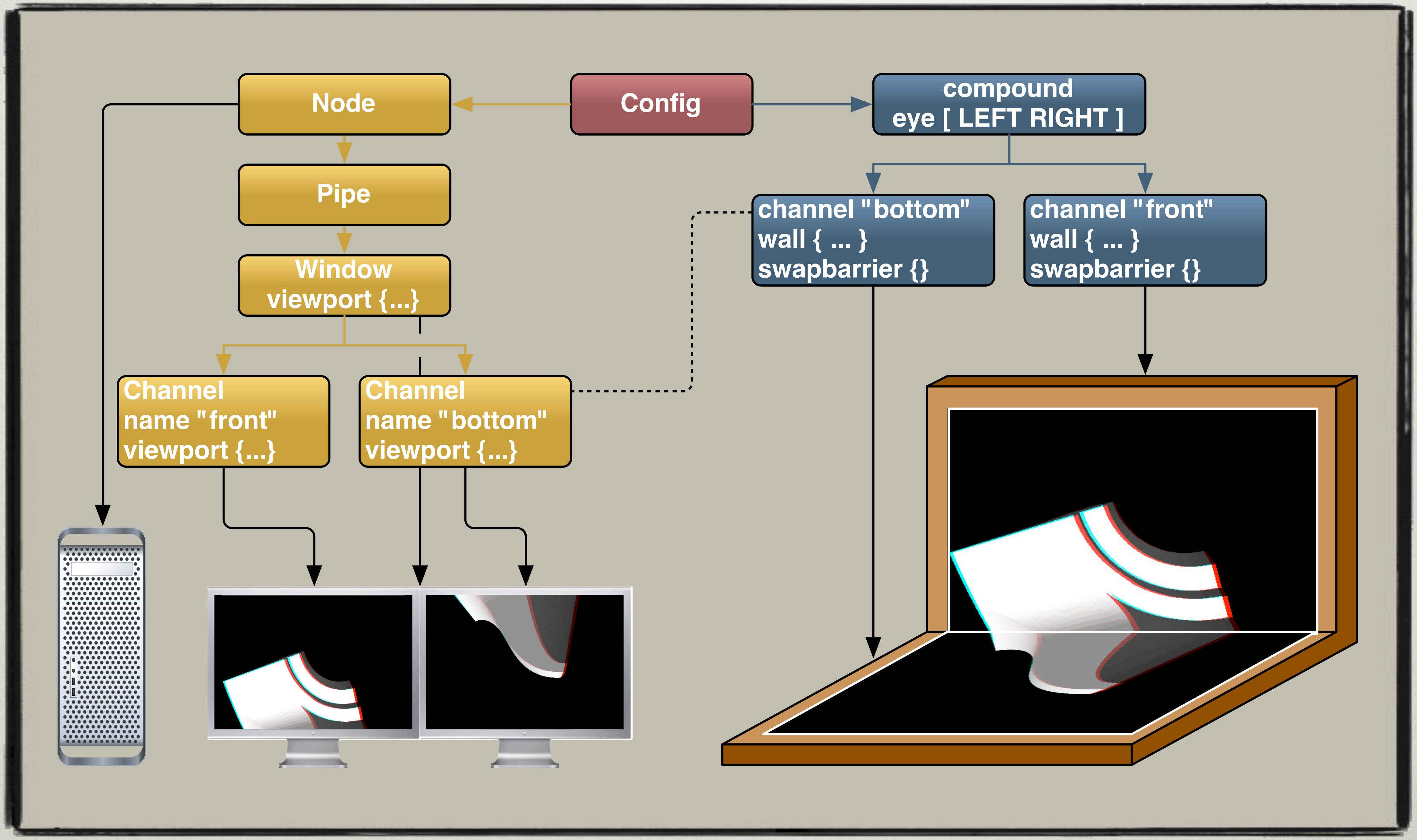
Resource-based

- Hierarchical resource description: Node→Pipe→Window→Channel
  - **Node** is a single computer in the cluster
  - **Pipe** is a graphics card and rendering *thread*
  - **Window** is an OpenGL drawable
  - **Channel** is a viewport within a window
- Resource usage: **compound tree**

Compound Trees

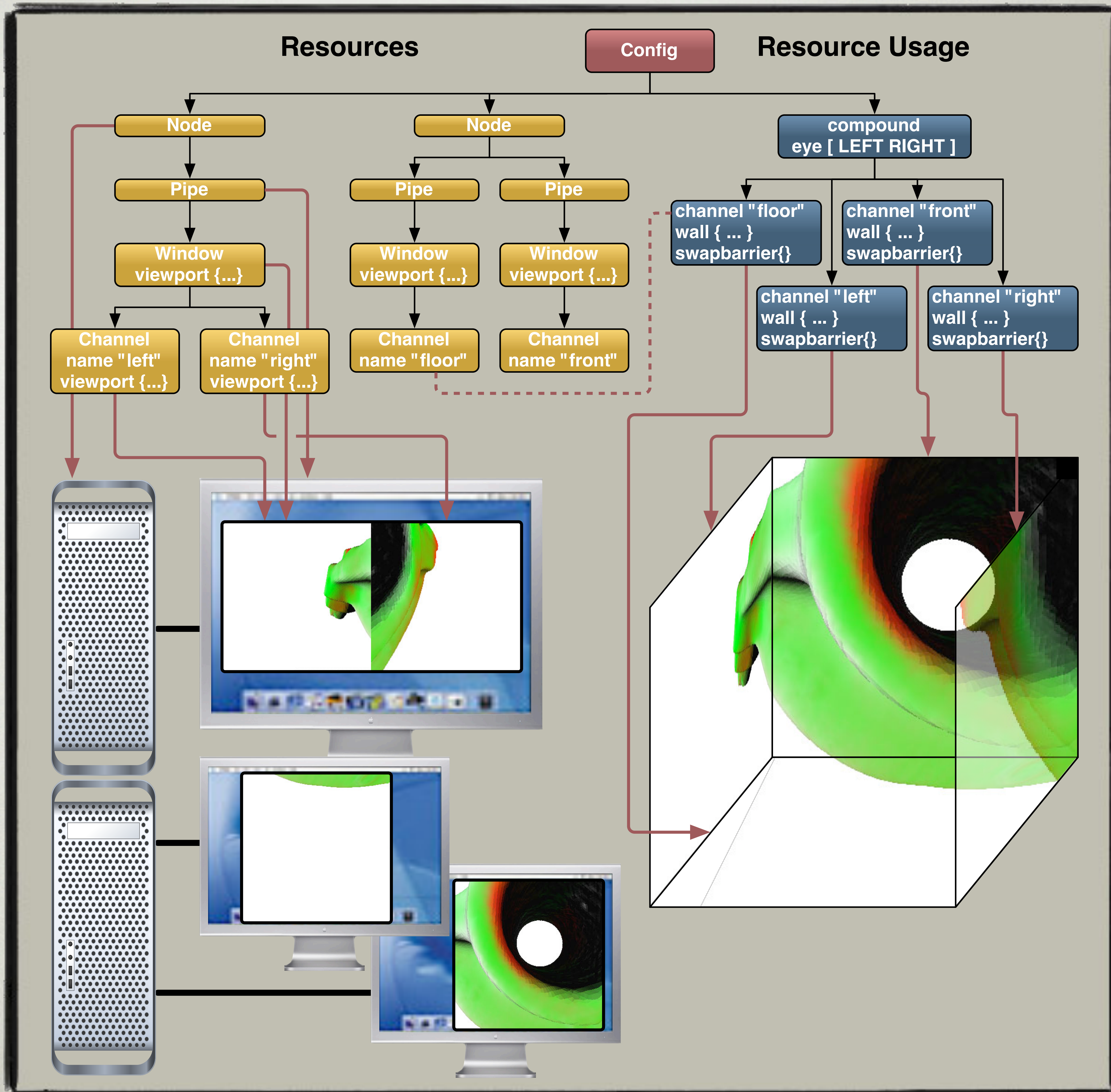
- Description of resource usage and parallel task distribution
    - easy specification via text configuration files

Holobench



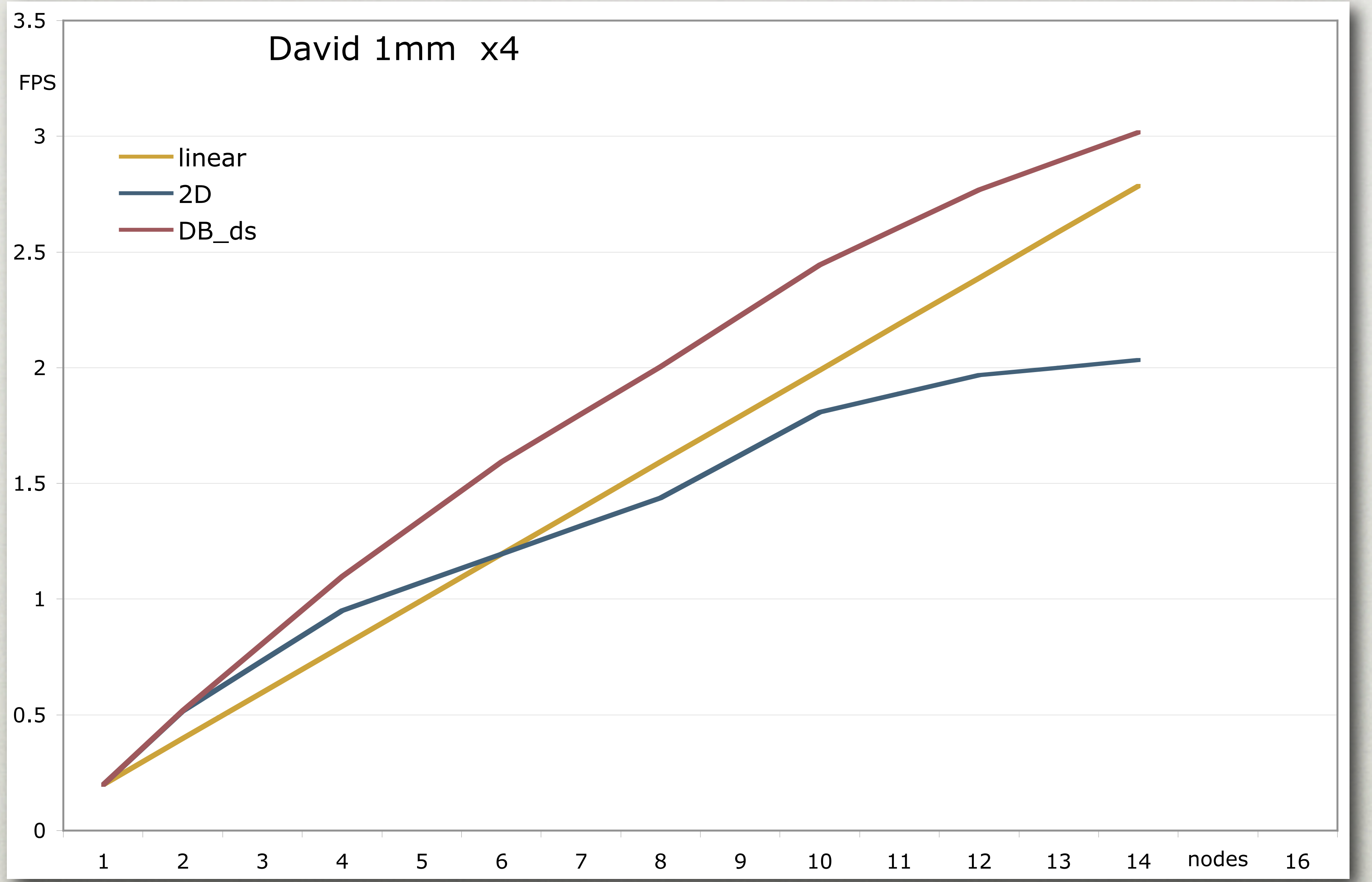
VMML
visualization and multimedia lab
university of zürich

Cave



VMML
visualization and multimedia lab
university of zürich

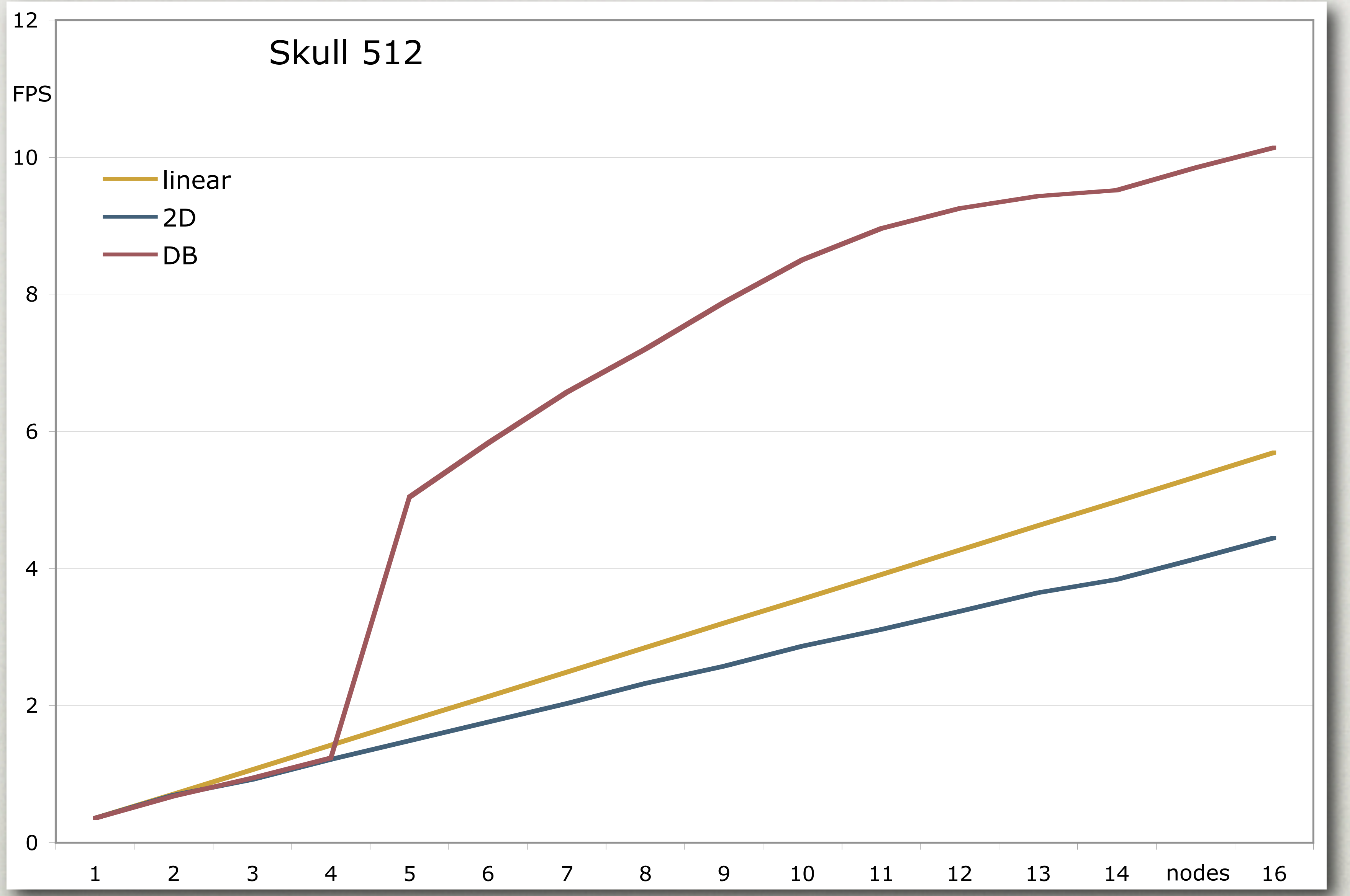
Scalability



225M triangle model

VMML
visualization and multimedia lab
university of zürich

Scalability



512³ voxel model

VMML
visualization and multimedia lab
university of zürich

Open Source

- LGPL license
- Open standard for scalable graphics
- Clusters and shared memory system supported
- More on www.equalizergraphics.com