Boeing Technology
Information Technology

Real-time, Interactive Massive Model Visualization

Philipp Slusallek, Saarland University
Dave Kasik, The Boeing Company

Course Outline and Speakers

- **9:00 – 10:30**
  - **Dave Kasik (Boeing)**
  - **Sung-eui Yoon (Lawrence Livermore Labs / University of North Carolina)**
- **10:30 – 11:00**
  - **Break**
- **11:00 – 12:30**
  - **Abe Stephens (University of Utah)**
  - **Beat Bruderlin (Technical University of Ilmenau)**
- **12:30 – 14:00**
  - **Lunch**
- **14:00 – 15:30**
  - **Philipp Slusallek, Andreas Dietrich (Saarland University)**
  - **Enrico Gobbetti (CRS4)**
- **15:30 – 16:00**
  - **Break**
- **16:00 – 17:30**
  - **Wagner Correa (IBM TJ Watson Research)**
  - **Inigo Quilez (VRContext)**

Motivation and Challenges in Real-time, Interactive Massive Model Visualization

Dave Kasik
Technical Fellow
The Boeing Company
Seattle WA USA
david.j.kasik@boeing.com
+1-425-830-4276

Section Goal

- **Provide understanding of:**
  - **Usage scenarios for interactive, massive model visualization.**
  - **The technology implications of interactive, massive model visualization.**
  - **How the user community can assist the research community.**

Section Outline

- **Motivation for effort from a user's perspective, including sample use cases**
- **Characterization of user tasks that can be addressed by visual analysis**
- **General processing architecture alternatives**
  - **Client-based**
  - **Hybrid client-server**
  - **Server-based**
- **Contrast of issues between GPU and CPU-based approaches**
- **Additional technical challenges:**
  - **Network impact**
  - **Pre-processing**
  - **Version management**
  - **Rigid body motion**
  - **Collision detection**
- **Pragmatics of getting data released to the research community**

Data Explosion

- **All storage media produced about 5 exabytes of new information in 2002.**
  - **92% was stored on magnetic media, mostly hard disks.**
- **This amount of new information is about double of the amount stored in 1999.**
- **Information flows through electronic channels (telephone, radio, TV, and the Internet) contained ~18 exabytes of new information in 2002.**
  - **This is 3 1/2 times more than is stored.**
  - **98% is voice and data sent telephonically via fixed lines and wireless**

What Do These Numbers Mean?

- **Kilobyte (KB) = 1,000 bytes, 10^3**
  - **2 KB: Typewritten page**
- **Megabyte (MB) = 1,000,000 bytes, 10^6**
  - **Small novel**
- **Gigabyte (GB) = 1,000,000,000 bytes, 10^9**
  - **Pickup truck filled with books**
- **Terabyte (TB) = 1,000,000,000,000 bytes, 10^{12}**
  - **50,000 trees made into paper**
  - **2 TB: An academic research library**
- **Petabyte (PB) = 1,000,000,000,000,000 bytes, 10^{15}**
  - **200 PB: All printed material**
- **Exabyte (EB) = 1,000,000,000,000,000,000 bytes, 10^{18}**
  - **2 EB: Total volume of information generated in 1999**
  - **5 EB: All words ever spoken by human beings**

Human Visual Communication Processor

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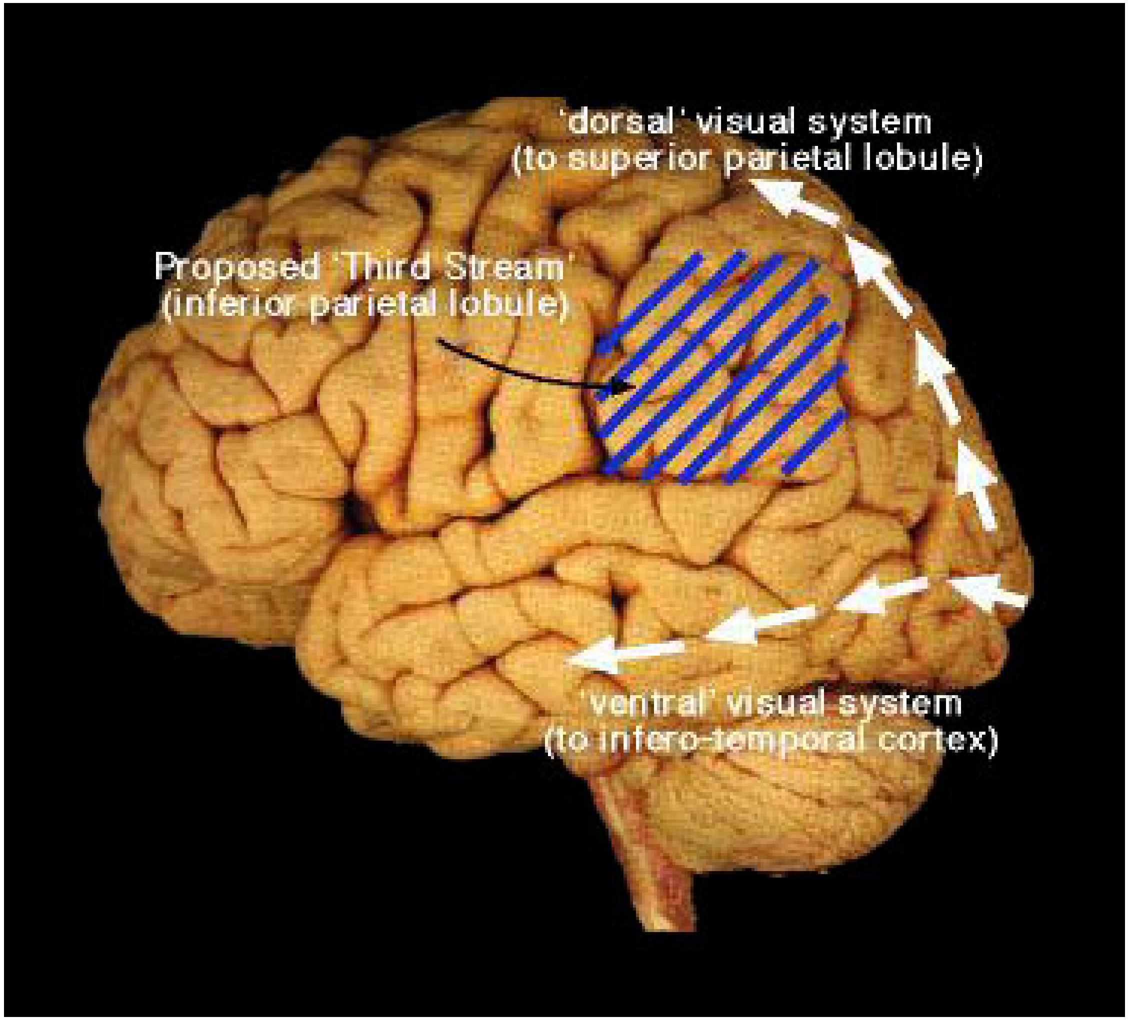

Buxton’s Conundrum

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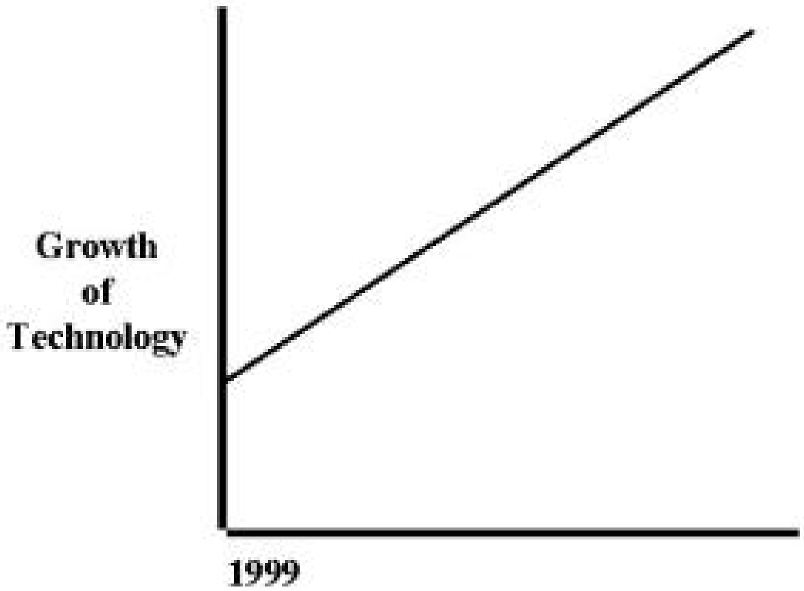
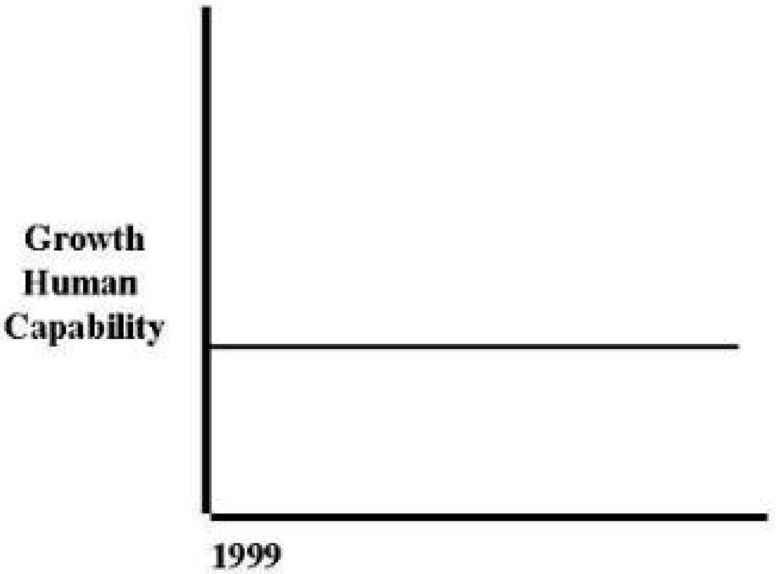




Moore’s Law

God’s Law

Use Cases

- **What can a user do with interactive visualization alone?**

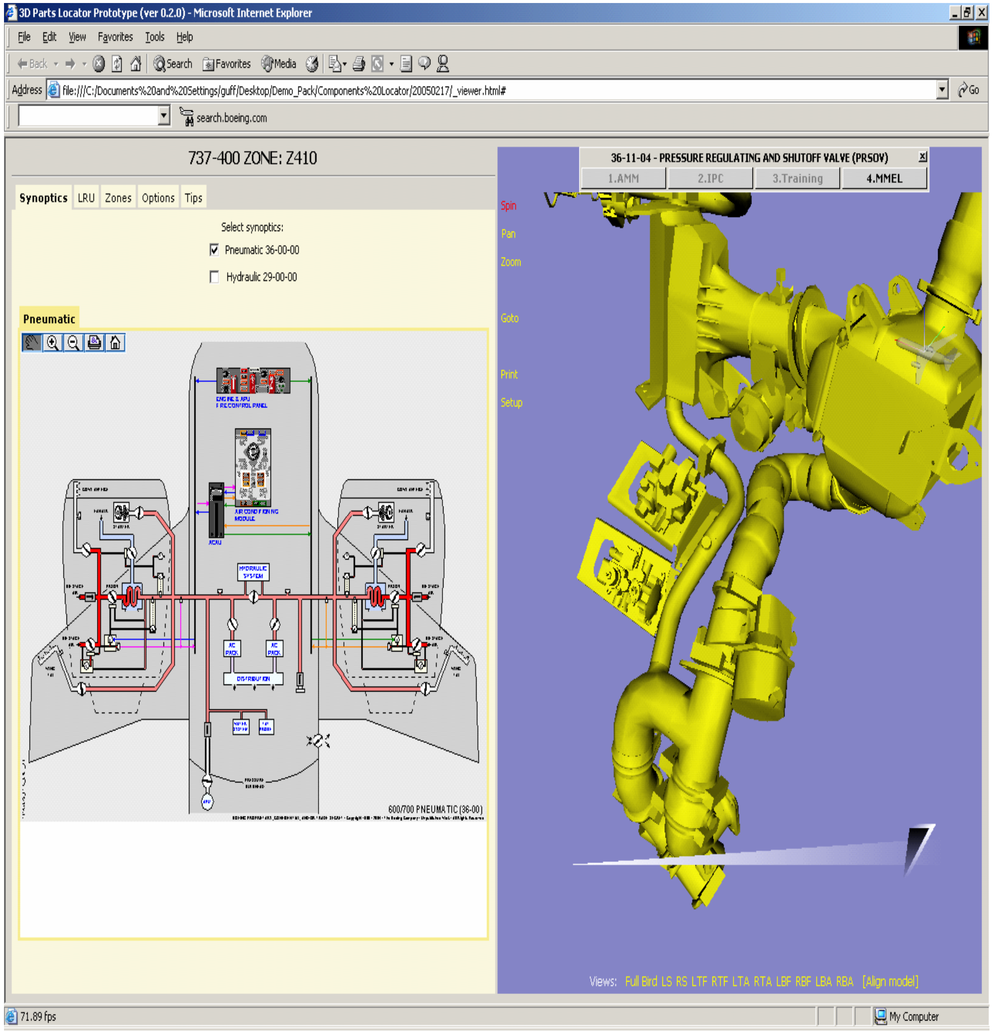
Visual Task Analysis

- **Find an object in a complex scene.**
- **Focus on the found object to better understand surface characteristics (e.g., smoothness, roughness).**
- **Once the object is found, look at objects in the immediately surrounding volume.**
- **Visually scan the scene.**
- **Observe dynamics in the entire scene (conventionally by animation).**
- **Work with multiple versions of the same set of objects to compare the two sets.**
- **More detail in DJ Kasik, "Strategies for Consistent Image Partitioning", IEEE Multimedia, Jan-Mar, 2004, pp. 32-41.**

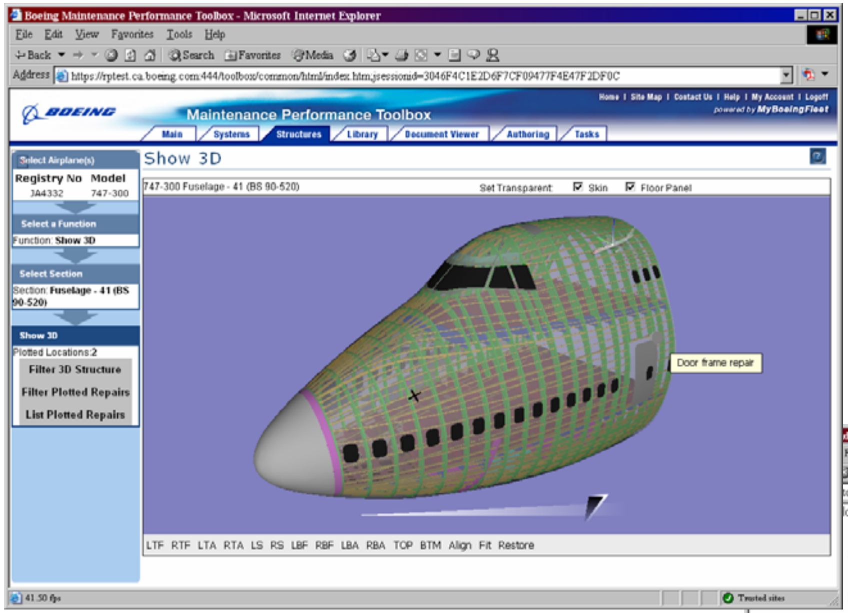
Potential Applications

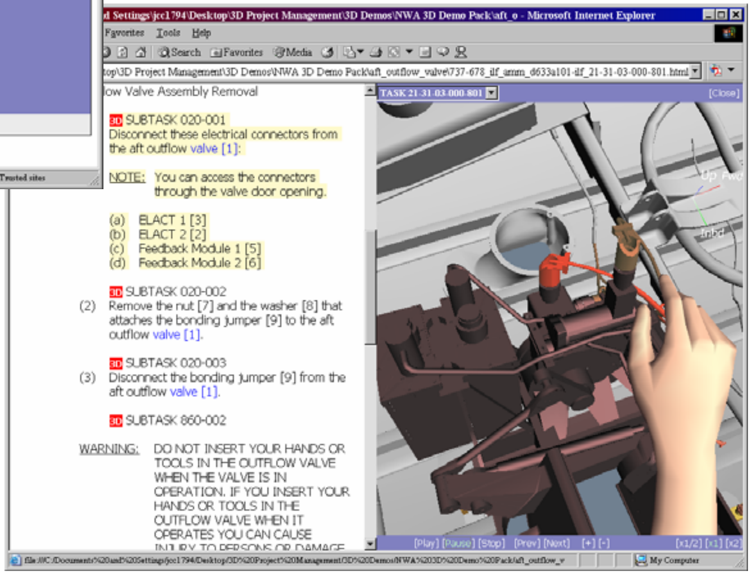
- **Design reviews**
- **Engineering analysis (loads, CFD, etc.)**
- **Safety**
- **Survivability**
- **Part context**
- **Reverse engineering from massive scans**
- **Quality assurance inspection**
- **Manufacturing instructions**
- **Part catalogs**
- **Training**
- **Maintenance instructions**
- **Sales and marketing**
- **Basically, any process where quick navigation is needed to go anywhere in a digital model**

Concrete Example 1 – Tracing Systems



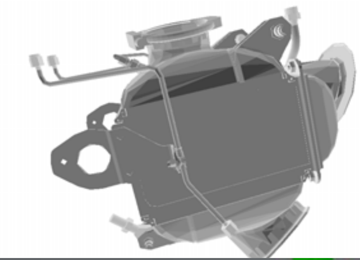
Concrete Example 2 – Maintenance Tasks



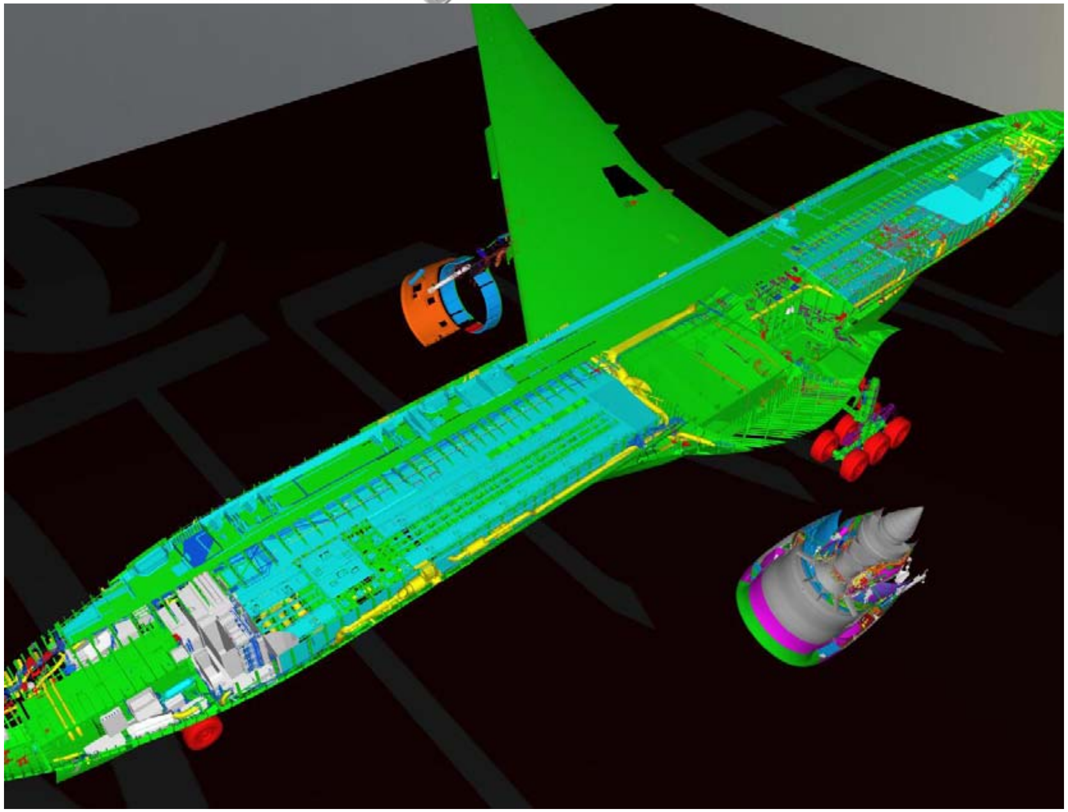


Concrete Example 3 – Design Review

- **Find this**



in this…



What Makes a Visualization Session Interactive?

- **Model load time: instantaneous.**
  - **For groups, 'instantaneous' translates to less than one minute.**
  - **For an individual, five minutes just seems like an eternity unless the person can effectively time share tasks.**
  - **Reality: the faster the better.**
- **'Flying' time: New transformation matrices that respond to mouse action.**
  - **Ideally, 16 Hz (the human flicker fusion threshold for video) or faster.**
  - **Practically, 10 Hz or faster.**
- **Graphical selection. Feedback appears in .25 seconds or less.**

Processing Architecture Alternatives

- **Virtual Terminal**
- **Remote Data**
- **Local Data**

Virtual Terminal

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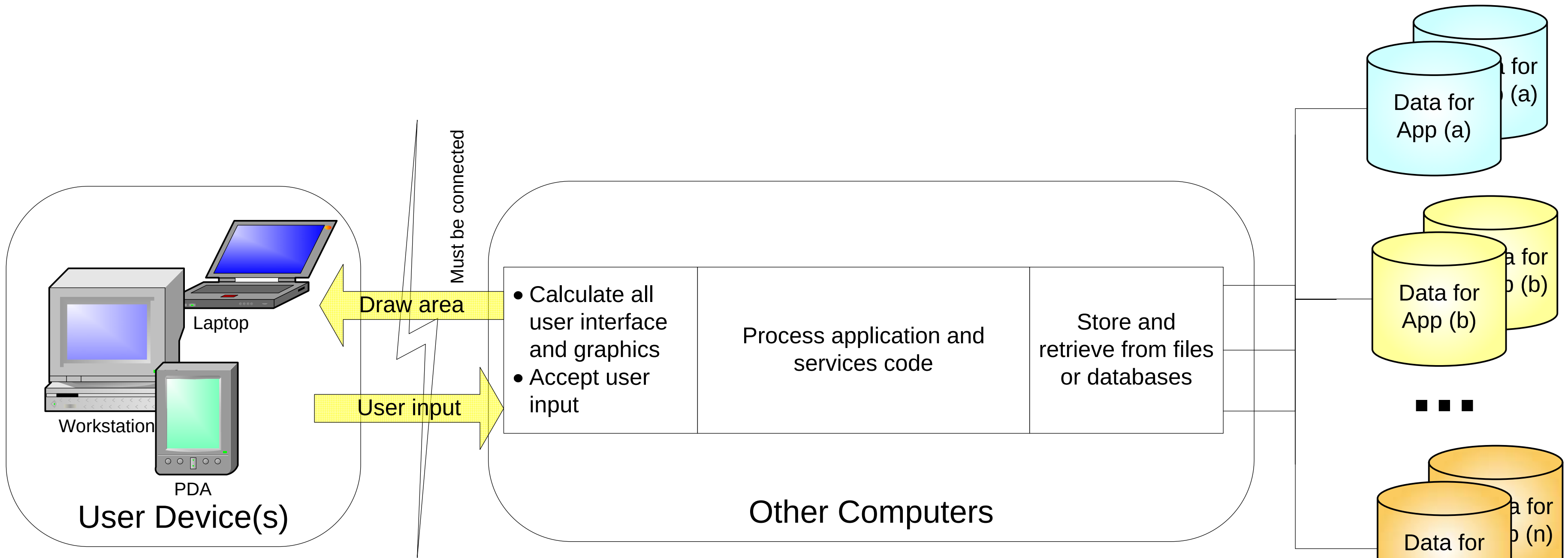


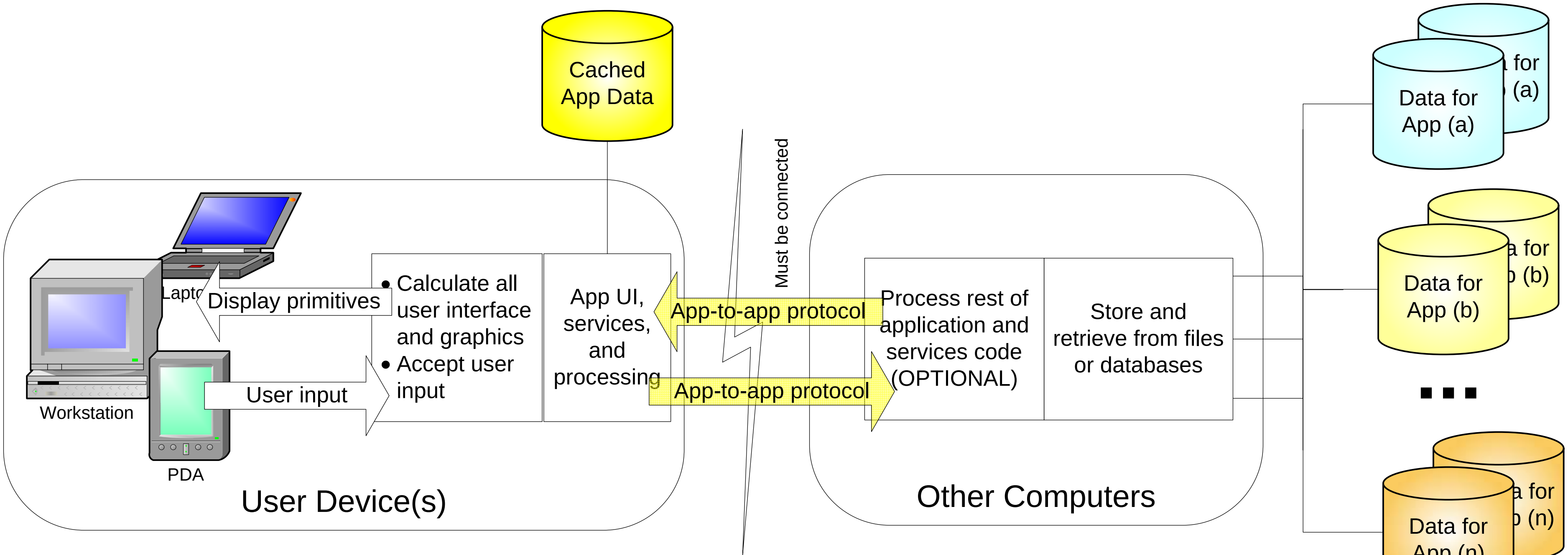
Example device software:

- Windows ICA
- Virtual Network Computing (VNC)

Any applications that run successfully on Operating Systems

- Windows Terminal Server, Shared NT (ICA)
- Citrix Metaframe, Shared NT (ICA)
- Linux (VNC)
- Proprietary UNIX (VNC)

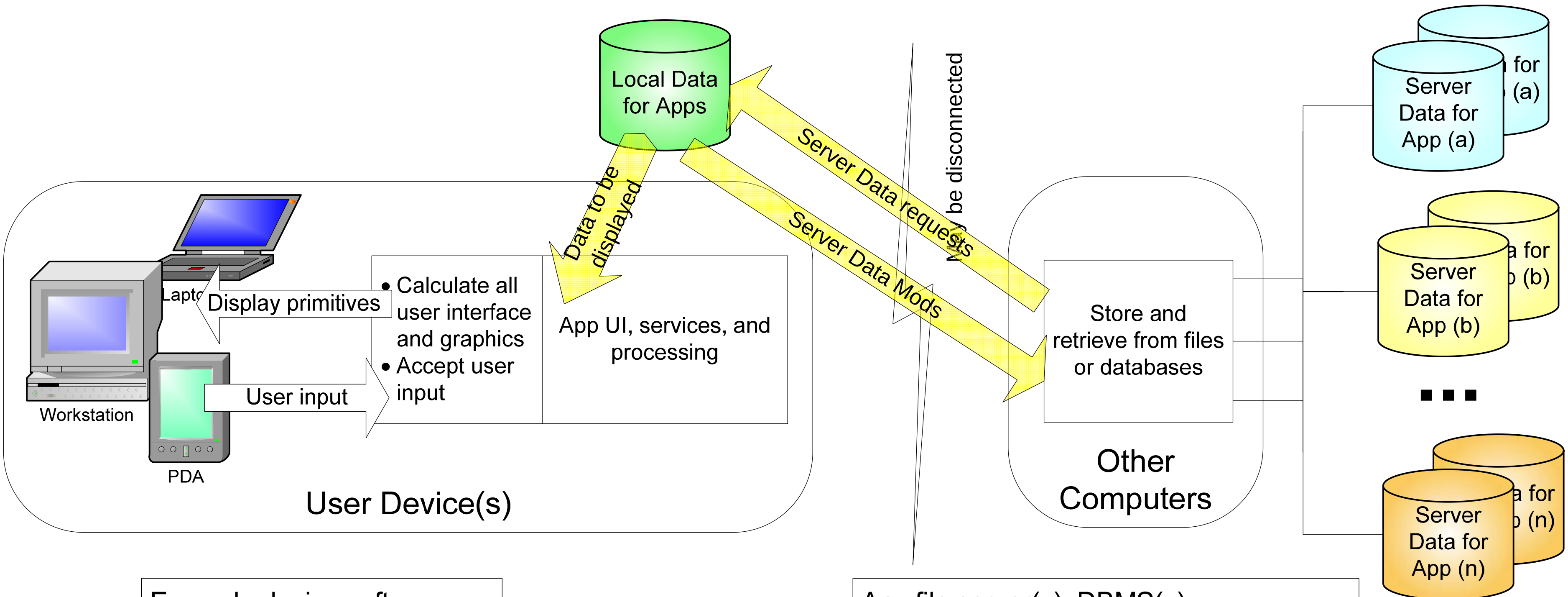
Remote Data



Example device software:
- OpenGL
- X-Windows
- Java3D
- SWING
- Motif
- Netscape, Internet Explorer with applets
- Direct3D
- Windows UI
- Custom UIMS/Widgets

Any applications that run successfully on Operating Systems
- UNIX (Solaris, AIX, HP/UX)
- Linux
- Windows

Local Data



Example device software:
- OpenGL
- X-Windows
- Java3D
- SWING
- Motif
- Direct3D
- Windows UI
- Custom UIMS/Widgets

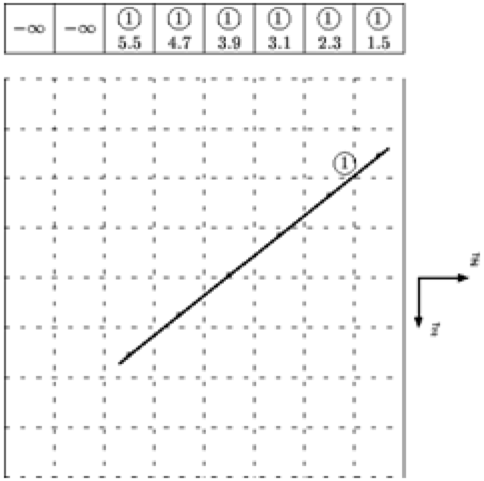
Any file server(s), DBMS(s), Warehouse(s), or Mart(s) that run on:
- Proprietary UNIX (Solaris, AIX, HP/UX)
- Linux
- Windows NT

Rendering Approaches

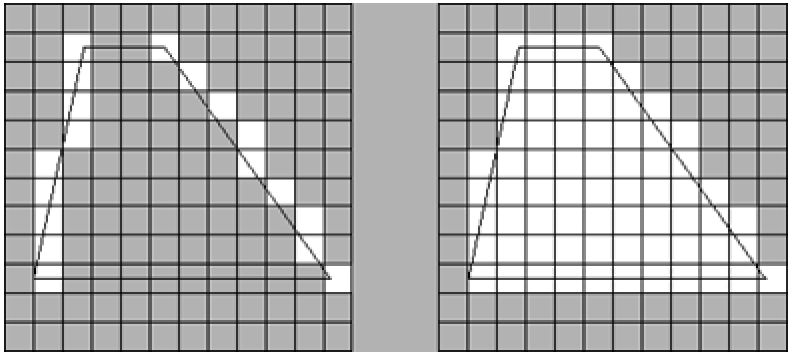
- **GPU vs. CPU**
- **Or, z-buffer vs. ray tracing**

Z-Buffer Instant

- **Z-buffering works by testing pixel depth and comparing the current z-coordinate with stored data in the *z-buffer* that holds information about each pixel's last z-coordinate.**
- **The pixel closest to the viewer is the one displayed**
- **Must 'rasterize' each polygon.**
- **Works on a scan line-by-scan line basis.**
- **Simple enough to be done in hardware.**
- **Because this is a pseudo-sort, difficult to be done in parallel.**



Basic Z Buffer



Rasterizing a Polygon

Single GPU Processing Architecture

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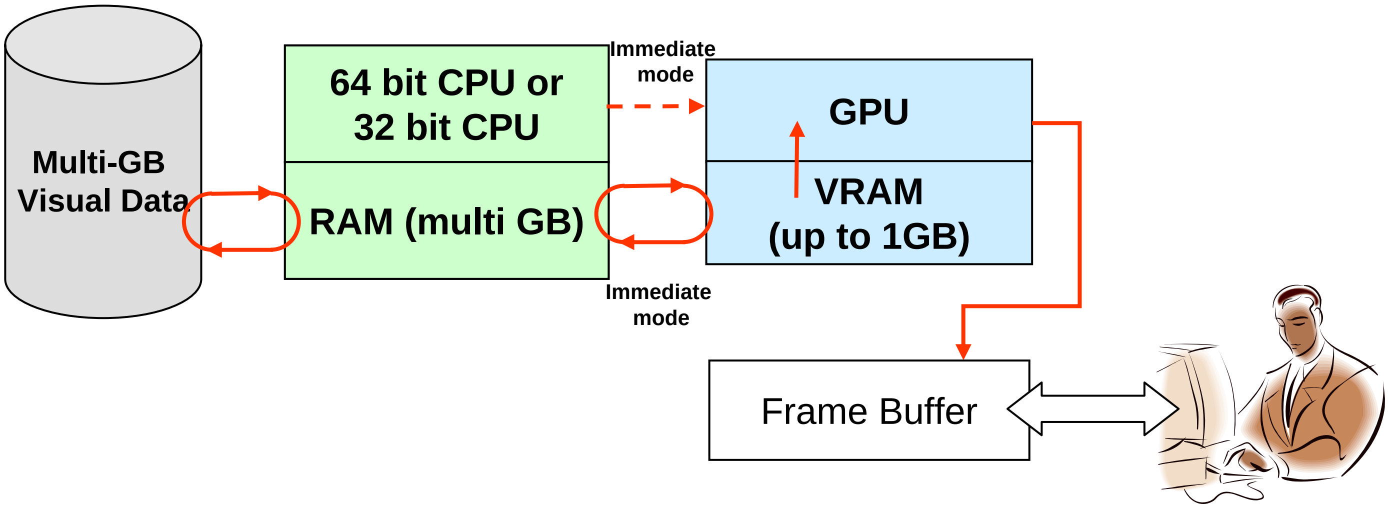

- **A capability to throttle data transfer to fill GPU memory or decrease the amount of data processed for immediate mode is needed long term (5 years), even with 64-bit CPUs.**

Multi-GPU Processing Architecture

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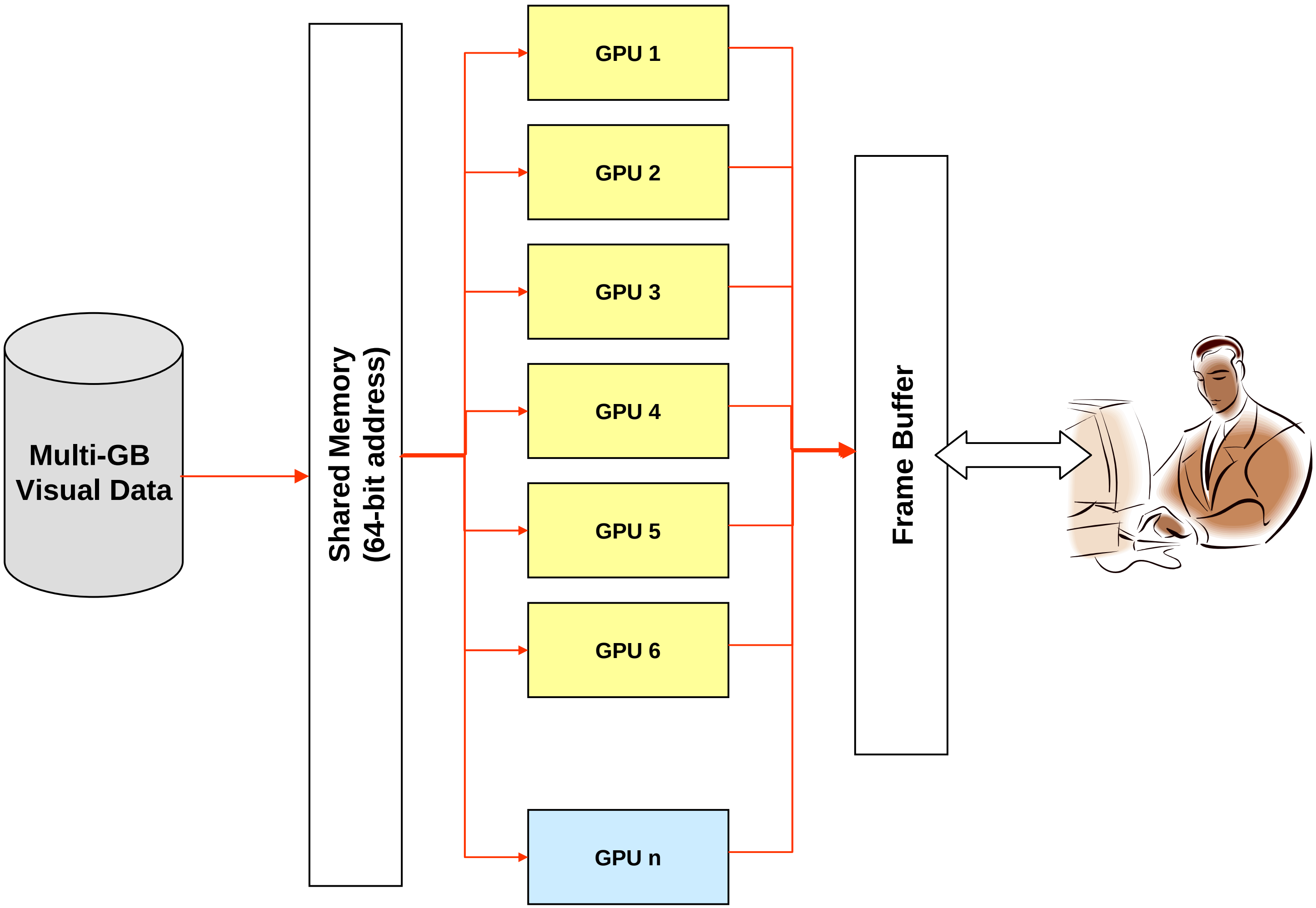
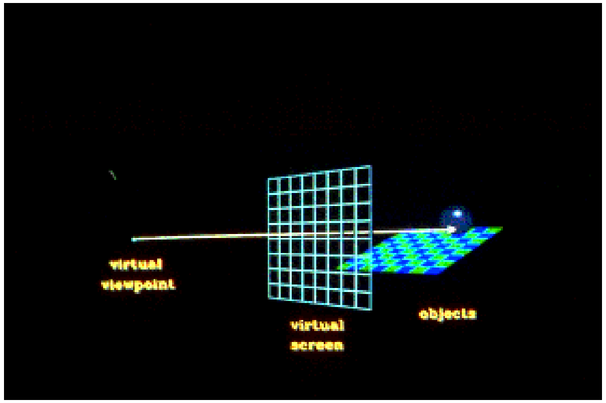
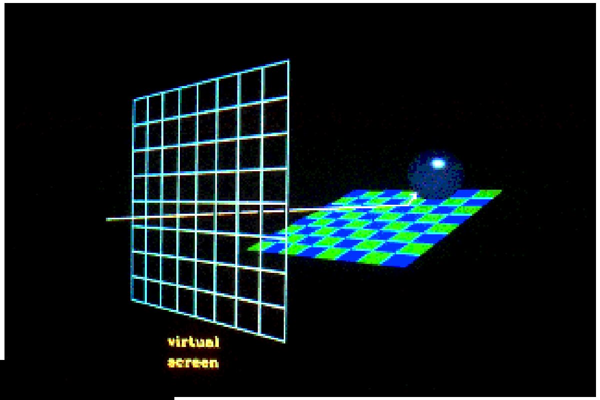


Ray-tracing Instant

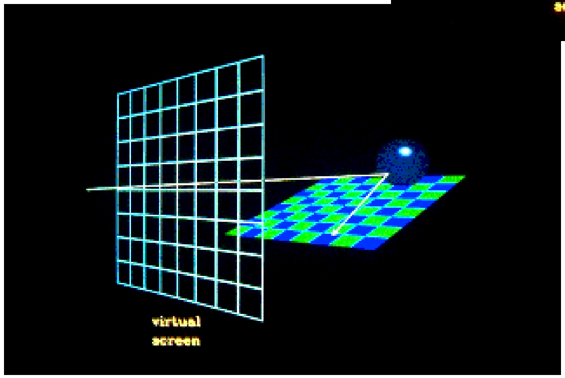
Fire a ray from the camera/eye at the scene and determine what it hits.



Use a shadow ray only after a ray hits an object.



Fire a reflected ray (if material properties warrant) to determine other colors until recursion quits.



Easily parallelized.

Multi-CPU Ray-tracing Processing Architecture

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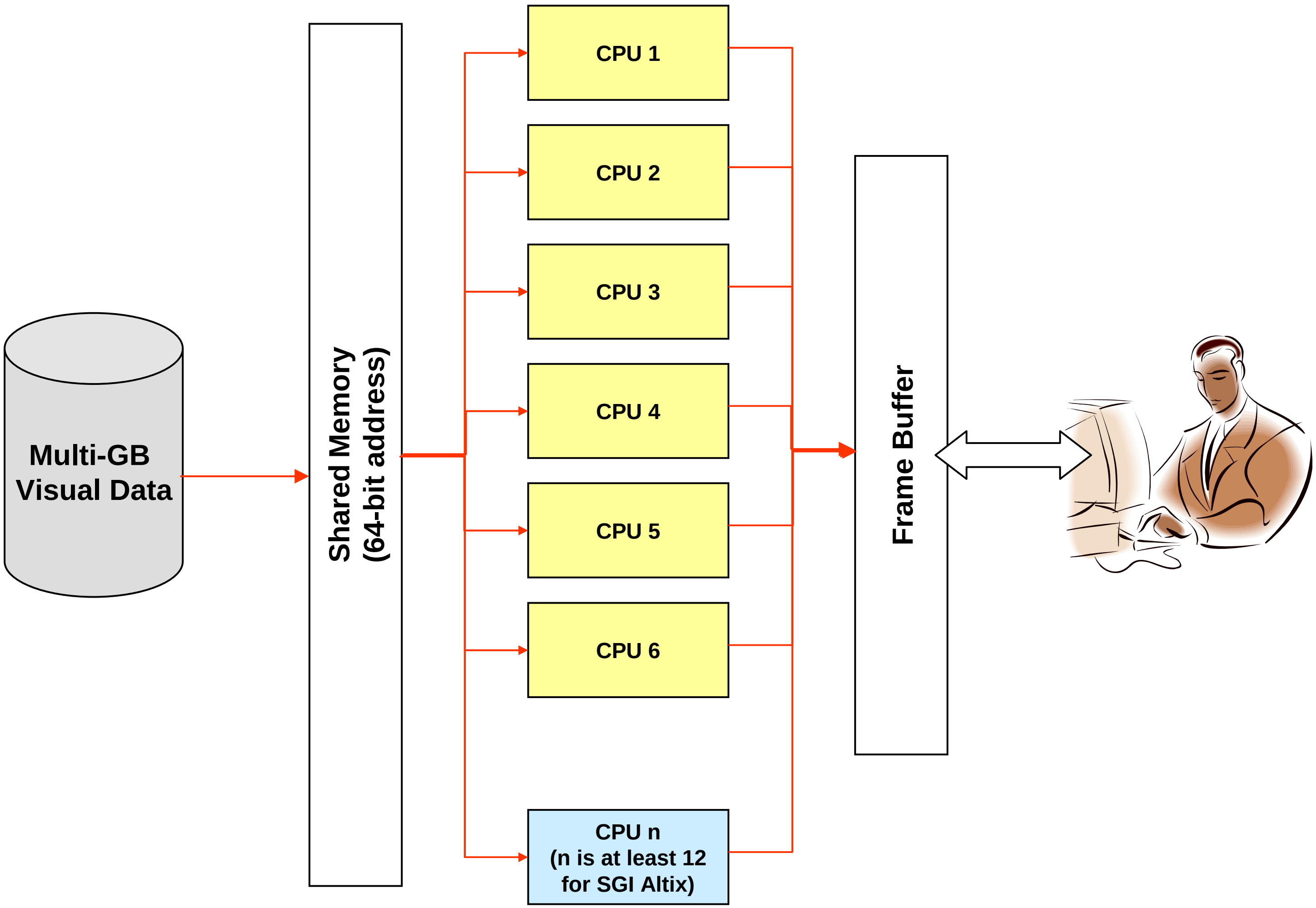

Hardware Assisted Ray-Tracing Notional Architecture

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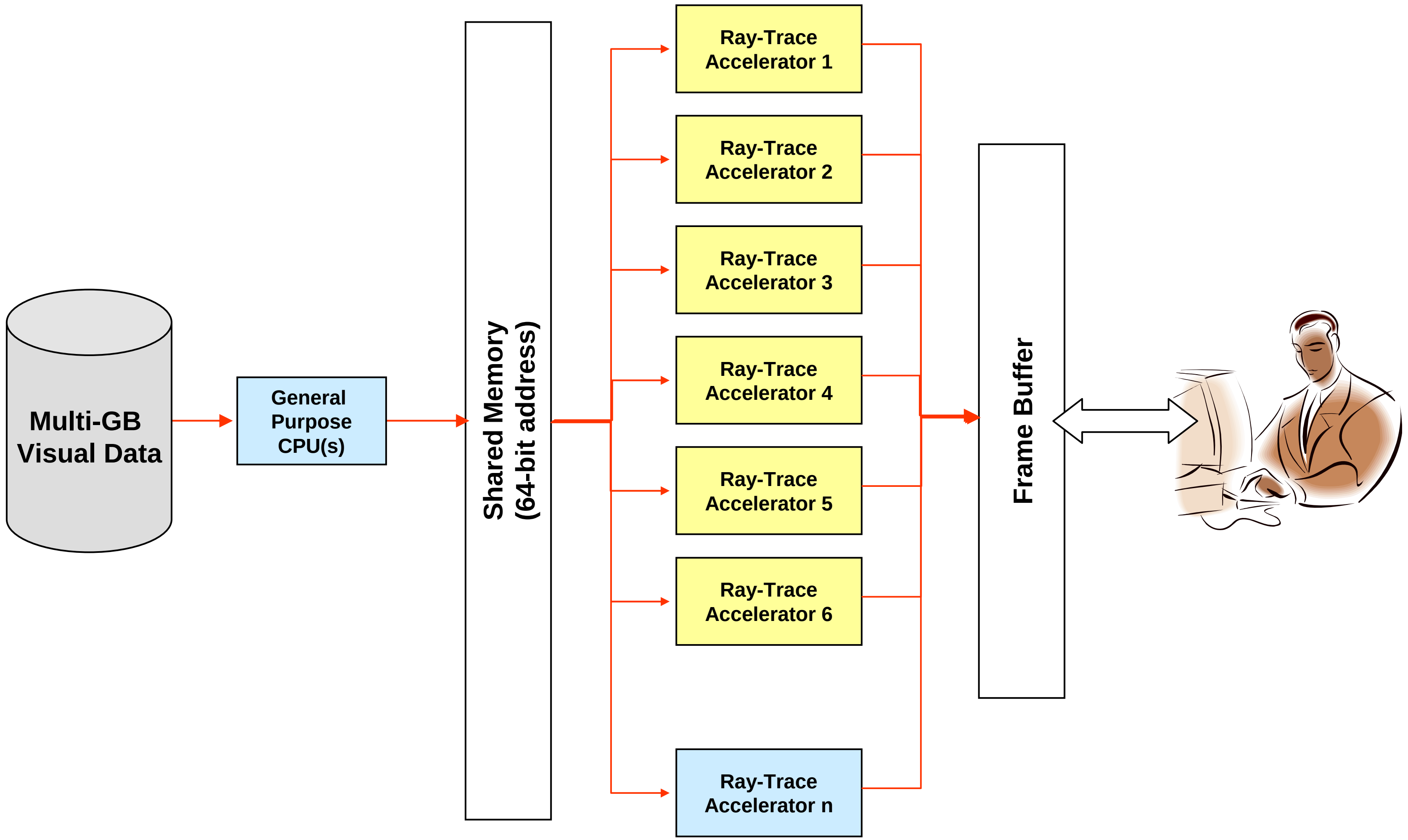

Other Technical Challenges

- **Network impact**
- **Pre-processing**
- **Collision detection**
- **Rigid body motion**
- **Visual model update**

Network Impact

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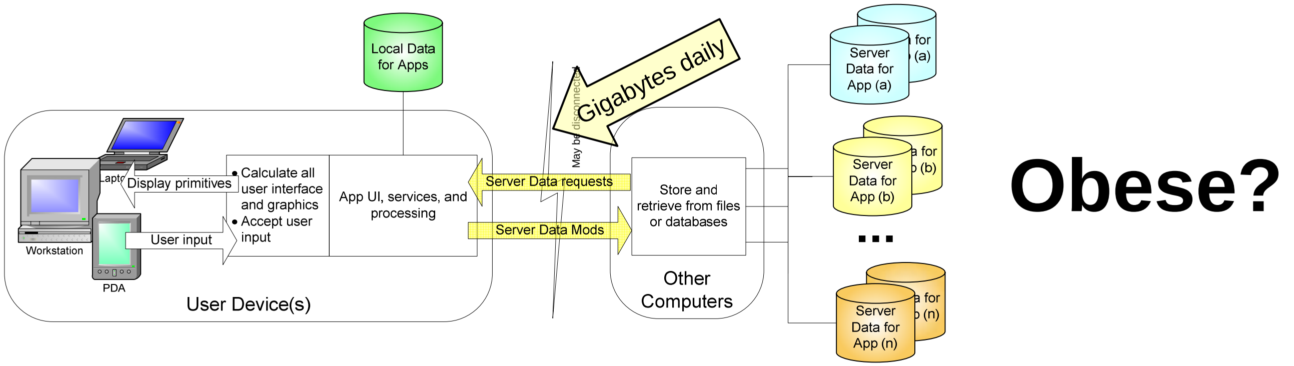
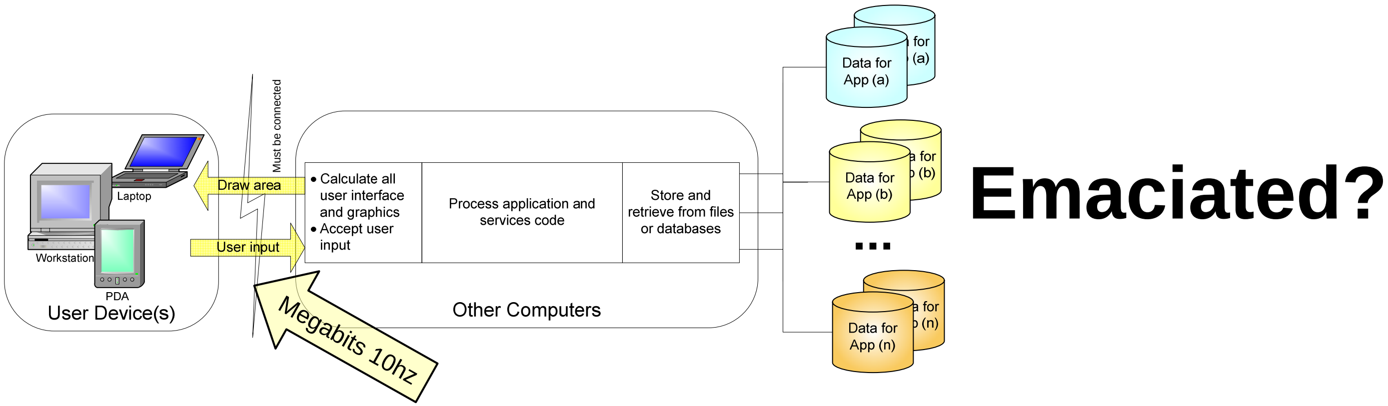
- **Obese, emaciated, or somewhere in between?**
- **Massive 3D data easily causes gigabyte data downloads (obese).**
- **Real-time interaction easily consumes megabits 10 times per second (emaciated).**





Pre-processing

- **All current approaches (both GPU and CPU) pre-process to get interactive performance.**
- **Routinely costs hours.**

Version Management

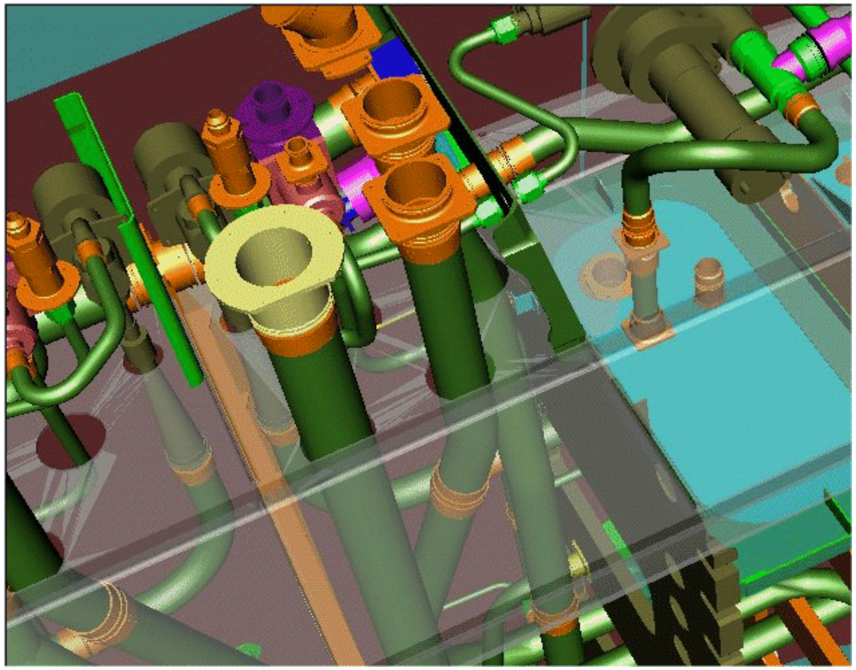
- **A detailed design activity may release hundreds of new part versions nightly.**
- **The base model easily contains hundreds of thousands of parts.**
- **Two issues:**
  - **Pre-processing cost to handle the new versions.**
  - **Methods to select which version should be displayed.**

Animation

- **Rigid body motion allows parts to move relative to one another.**
- **Can be the result of all sorts of simulations:**
  - **Mechanisms**
  - **Manufacturing assembly plans**
  - **Training**
  - **…**
- **Simulations that result in shape deformation are much more difficult.**

Collision Detection

- **Common task in a design review is to figure out what objects erroneously share the same space.**
- **Subtle problem because some tangent conditions (e.g., parts bolted together) are OK or may be allowed to collide (e.g., flexible wire sheathing).**



Pragmatics of Data Release

- **Find the data owner.**
- **Be willing to work through a non-disclosure or proprietary information agreement.**
- **Be willing to subtly manipulate the data to remove intellectual property, export control, military sensitive, or other concerns that lawyers have.**
- **Be really patient.**

Summary

- **Outlined overall problem, usefulness quotient, and technical issues.**
- **The rest of the instructors will provide a deeper technical look and further examine the pragmatics of large model rendering in production.**