# MPIglut: Powerwall Programming made Easier

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# Talk Overview

- **MPIglut: lets serial glut OpenGL apps run in parallel atop MPI**
  - **Powerwall Hardware & Software**
  - **Parallel Rendering Software**
- **MPIglut code & runtime changes**
- **Application Performance**
- **Future work**

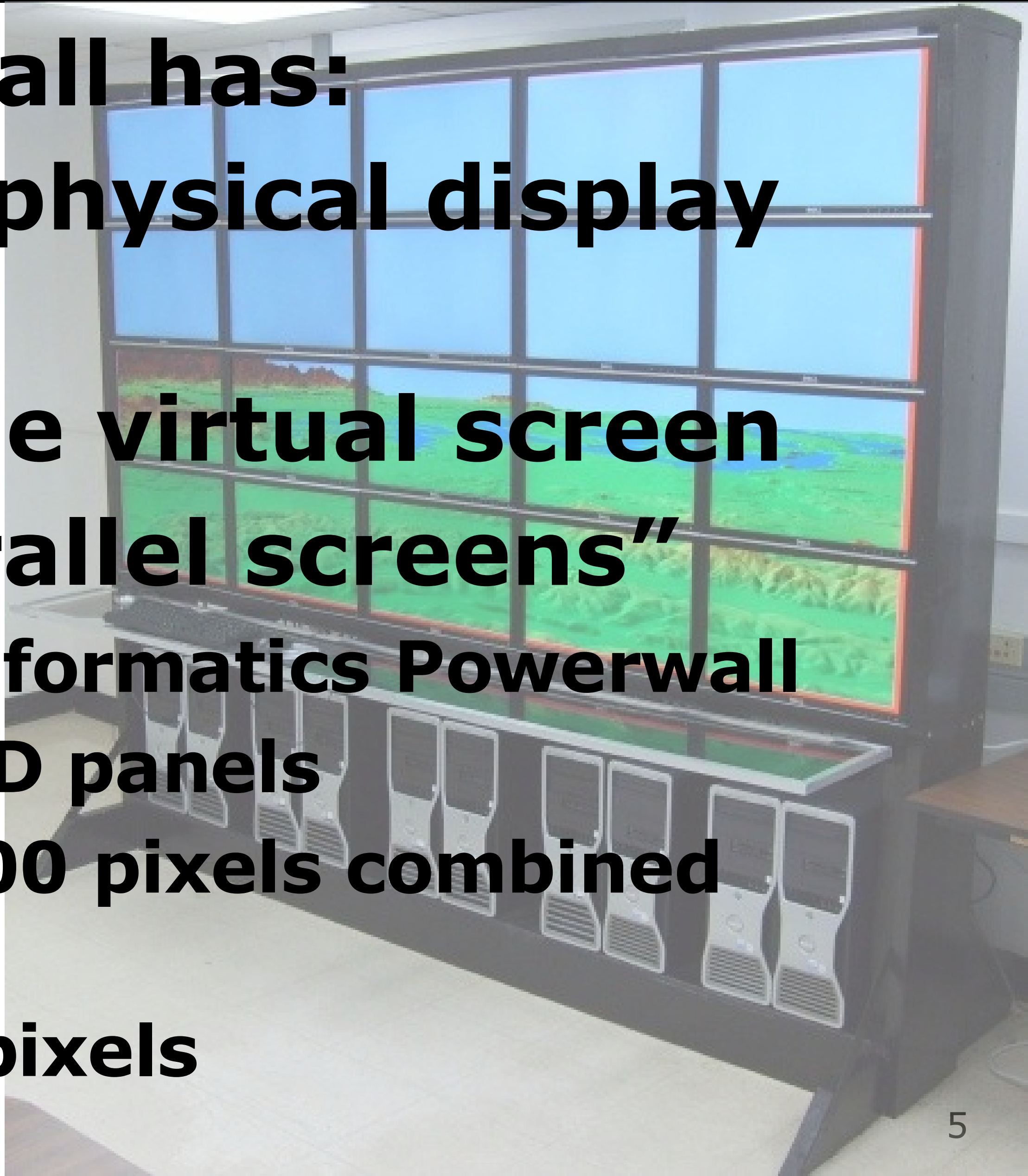
# MPIglut Basics

# MPIglut: Motivation

- Modern computing is <u>parallel</u>
  - Multi-Core CPUs, Clusters
    - Athlon 64 X<u>2</u>, Intel Core2 <u>Duo</u>
  - Multiple Multi-Unit GPUs
    - nVidia SLI, ATI CrossFire
  - Multiple Displays
- But languages and many existing applications are <u>sequential</u>
  - Software problem: run existing serial code on a parallel machine
  - Related: easily write parallel code

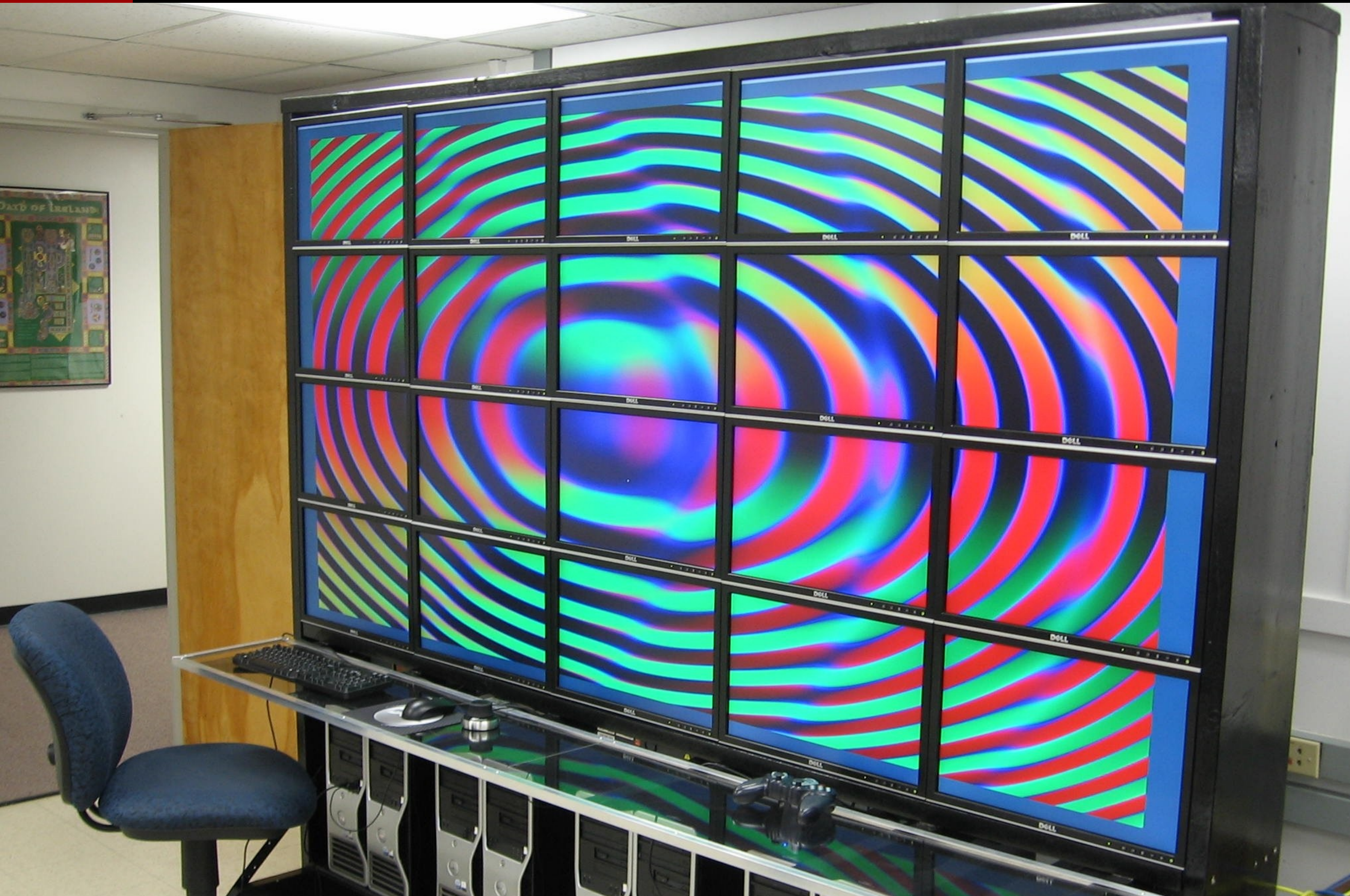
# What is a "Powerwall"?

- A powerwall has:
  - <u>Several</u> physical display devices
  - <u>One</u> large virtual screen
  - I.E. "parallel screens"
- UAF CS/Bioinformatics Powerwall
  - Twenty LCD panels
  - 9000 x 4500 pixels combined resolution
  - 35+ Megapixels



# Sequential OpenGL Application

# Parallel Powerwall Application



# MPIglut: The basic idea

- **Users compile their OpenGL/glut application using MPIglut, and it "just works" on the powerwall**
- **MPIglut's version of glutInit runs a separate copy of the application for each powerwall screen**
- **MPIglut <u>intercepts</u> glutInit, glViewport, and broadcasts user events over the network**
- **MPIglut's glViewport shifts to render <u>only</u> the local screen**

# MPIglut uses MPI parallel library

- **MPI: Message Passing Interface**
  - **Standardized communication library for distributed-memory parallel machines (like clusters)**
- **MPI runs over many networks; several software implementations**
  - **MPICH, OpenMPI, AMPI**
- **MPIglut uses MPI to compile (mpiCC), start-up (mpirun), event broadcast, and synchronization**
  - **MPIglut apps can call MPI too!**

# MPIglut uses glut sequential code

- **GL Utilities Toolkit**
  - **Portable window, event, and GUI functionality for OpenGL apps**
  - **De facto standard for small apps**
  - **Several implementations: Mark Kilgard original, FreeGLUT, ...**
  - **Totally sequential library, until now!**
- **MPIglut intercepts several calls**
  - **But many calls still unmodified**
  - **We run on a patched freeglut 2.4**
    - **Minor modification to window creation**

# Parallel Rendering Taxonomy

- Molnar's influential 1994 paper
  - Sort-first: send geometry across network before rasterization (GLX/DMX, Chromium)
  - Sort-middle: send scanlines across network during rasterization
  - Sort-last: send rendered pixels across the network after rendering (IBM's Scalable Graphics Engine, ATI CrossFire)

# Parallel Rendering Taxonomy

- **Expanded taxonomy:**
  - **Send-event (MPIglut, VR Juggler)**
    - **Send only user events (mouse clicks, keypresses). Just kilobytes/sec!**
  - **Send-database**
    - **Send application-level primitives, like terrain model. Can cache/replicate data!**
  - **Send-geometry (Molnar sort-first)**
  - **Send-scanlines (Molnar sort-middle)**
  - **Send-pixels (Molnar sort-last)**

# Code & Runtime Changes

# MPIglut Conversion: Original Code

```
#include <GL/glut.h>
void display(void) {
   glBegin(GL_TRIANGLES); ... glEnd();
   glutSwapBuffers();
}
void reshape(int x_size,int y_size) {
   glViewport(0,0,x_size,y_size);
   glLoadIdentity();
   gluLookAt(...);
}
...
int main(int argc,char *argv[]) {
   glutInit(&argc,argv);
   glutCreateWindow("Ello!");
   glutMouseFunc(...);
   ...
}
```

# MPIglut: Required Code Changes

```
#include <GL/mpiglut.h>
void display(void) {
   glBegin(GL_TRIANGLES); ... glEnd();
   glutSwapBuffers();
}
void
   glV
   glL
   gluLookAt(...);
}
...
int main(int argc,char *argv[]) {
   glutInit(&argc,argv);
   glutCreateWindow("Ello!");
   glutMouseFunc(...);
   ...
}
```

**This is the <u>only</u> source change. Or, you can just copy mpiglut.h over your old glut.h header!**

# MPIglut Runtime Changes: Init

```
#include <GL/mpiglut.h>
void display(void) {
   glBegin(GL_TRIANGLES); ... glEnd();
   glutSwapBuffers();
}
void reshape(int x_size,int y_size) {
   glViewport(0,0,x_size,y_size);
   glLoa
   gluLo
}
...
int main(int argc,char *argv[]) {
   glutInit(&argc,argv);
   glutCreateWindow("Ello!");
   glutMouseFunc(...);
   ...
}
```

**MPIglut starts a <u>separate</u> copy of the program (a "backend") to drive each powerwall screen**

# MPIglut Runtime Changes: Events

```
#include <GL/mpiglut.h>
void display(void) {
   glBegin(GL_TRIANGLES); ... glEnd();
   glutSwapBuffers();
}
void reshape(int x_size,int y_size) {
   glViewport(0,0,x_size,y_size);
   glLo
   gluL
}
...
int mai
   glut
   glutCreateWindow("Ello!");
   glutMouseFunc(...);
   ...
}
```

**Mouse and other user input events are collected and sent across the network.**
**Each backend gets <u>identical</u> user events (collective delivery)**

# MPIglut Runtime Changes: Sync

```
#include <GL/mpiglut.h>
void display(void) {
   glBegin(GL_TRIANGLES); ... glEnd();
   glutSwapBuffers();
}
void reshape(int x_size,int y_size) {
   glViewport(0,0,x_size,y_size);
   glLo
   gluL
}
...
int main(int argc,char *argv[]) {
   glutInit(&argc,argv);
   glutCreateWindow("Ello!");
   glutMouseFunc(...);
   ...
}
```

**Frame display is (optionally) synchronized across the cluster**

# MPIglut Runtime Changes: Coords

```
#include <GL/mpiglut.h>
void display(void) {
   glBegin(GL_TRIANGLES); ... glEnd();
   glutSwapBuffers();
}
void reshape(int x_size,int y_size) {
   glViewport(0,0,x_size,y_size);
   glLoadIdentity();
   gluLookAt(...);
}
...
int ma
   glu
   glu
   glutMouseFunc(...);
   ...
}
```

**User code works only in <u>global</u> coordinates, but MPIglut adjusts OpenGL's projection matrix to render only the <u>local</u> screen**

# MPIglut Runtime Non-Changes

```
#include <GL/mpiglut.h>
void display(void) {
   glBegin(GL_TRIANGLES); ... glEnd();
   glutSwapBuffers();
}
void re
   glVi
   glLo
   gluL
}
...
int ma
   glut
   glutCreateWindow("Ello!");
   glutMouseFunc(...);
   ...
}
```

**MPIglut does NOT intercept or interfere with rendering calls, so programmable shaders, vertex buffer objects, framebuffer objects, etc all run at full performance**

# MPIglut Assumptions/Limitations

- Each backend app must be able to render its part of its screen
  - Does not automatically imply a replicated database, if application uses matrix-based view culling
- Backend GUI events (redraws, window changes) are collective
  - All backends must stay in synch
  - Automatic for applications that are deterministic function of <u>events</u>
    - Non-synchronized: files, network, time

# MPIglut: Bottom Line

- Tiny source code change
- Parallelism hidden inside MPIglut
  - Application still “feels” sequential!
- Fairly major runtime changes
  - Multiple synchronized backends running in parallel
  - User input events communicated across network
  - OpenGL rendering coordinate system adjusted per-backend
  - But rendering calls are left alone

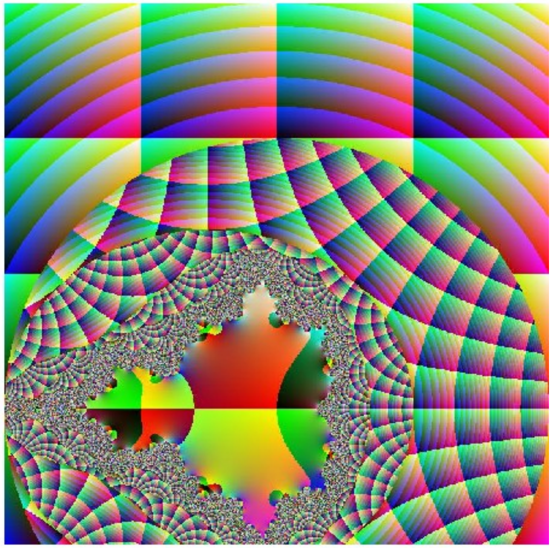
# Delivered Application Performance

# Performance Testing

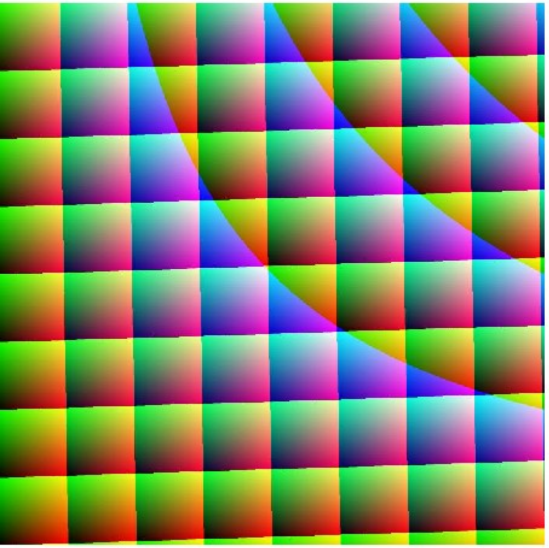
- **MPIglut programs perform about the same on 20 screens as they do on 1 screen**
- **We compared performance against two other packages for running unmodified OpenGL apps:**
  - **DMX: OpenGL GLX protocol interception and replication (MPIglut gets screen sizes via DMX)**
  - **Chromium: libgl OpenGL rendering call interception and routing**

# Benchmark Applications

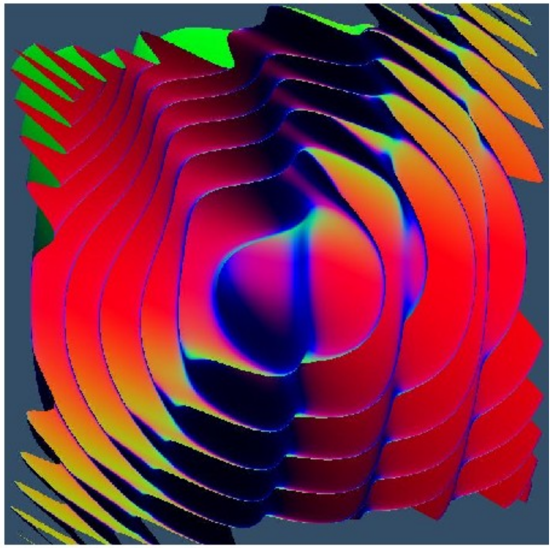
*basic*



*mandel*



*tex, tex_obj*



*vtx, vtx_obj*

*soar*

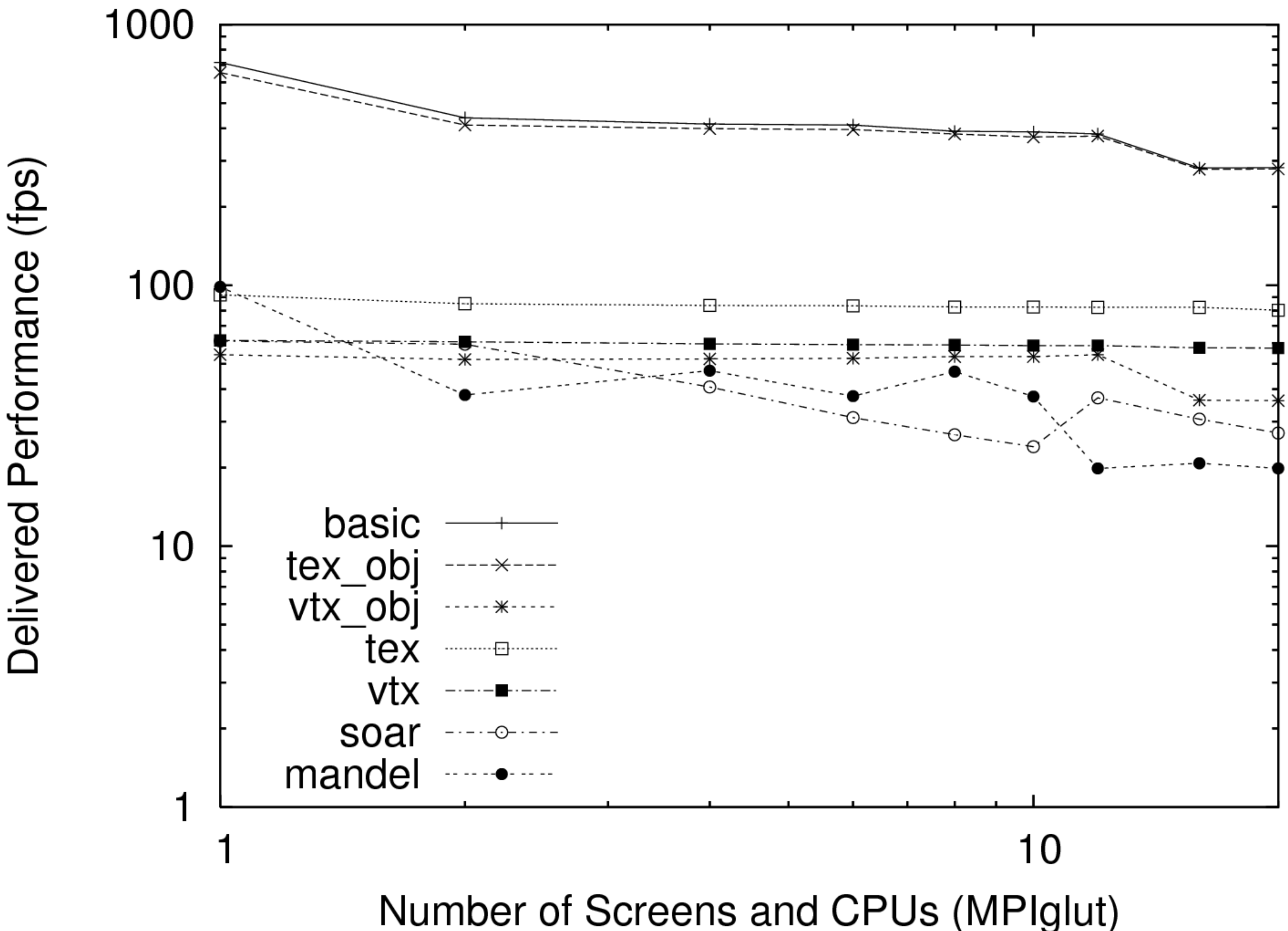
UAF CS Bioinformatics Powerwall

Switched Gigabit Ethernet Interconnect

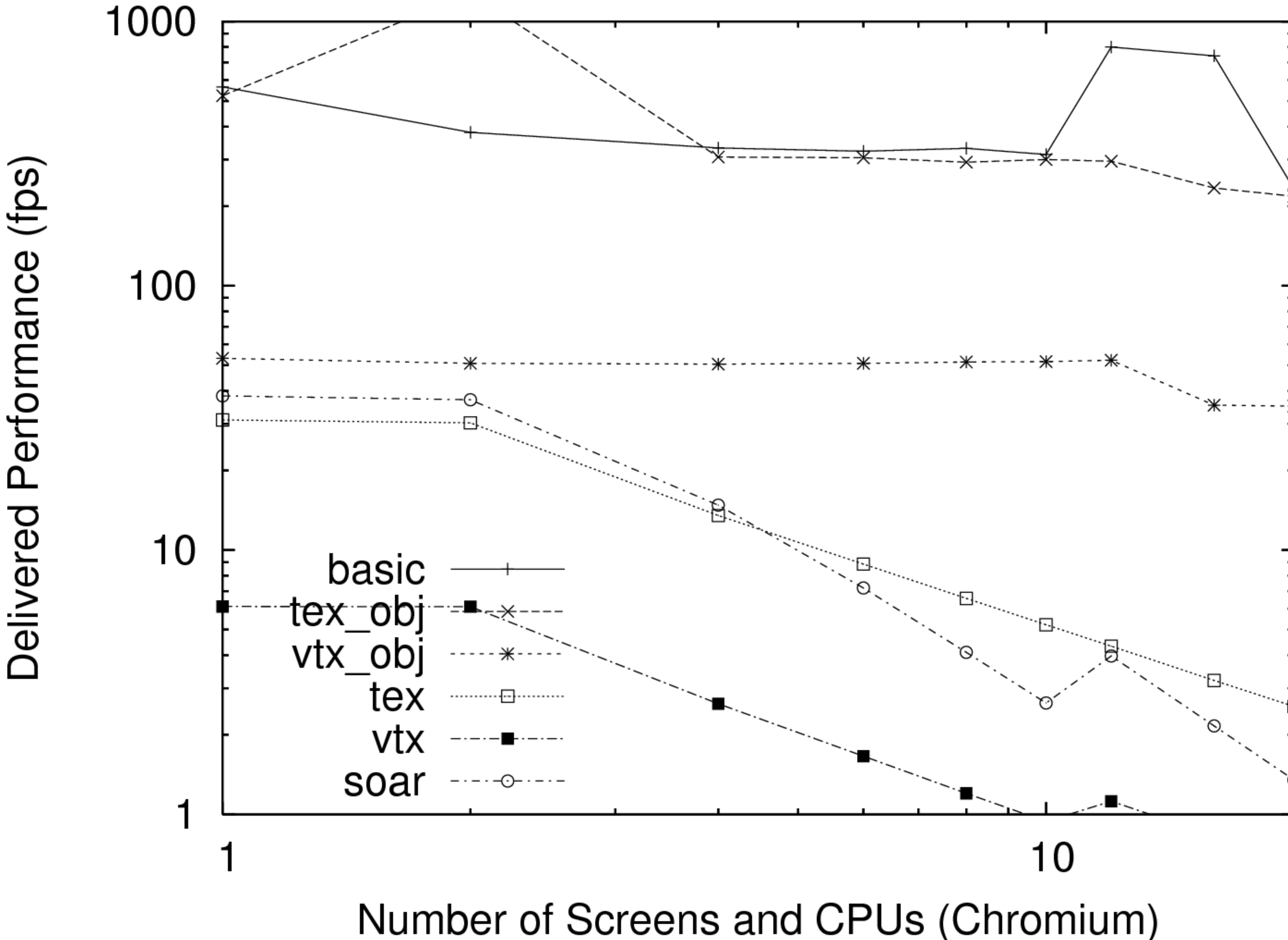
10 Dual-Core 2GB Linux Machines:

- 7 nVidia QuadroFX 3450
- 3 nVidia QuadroFX 1400

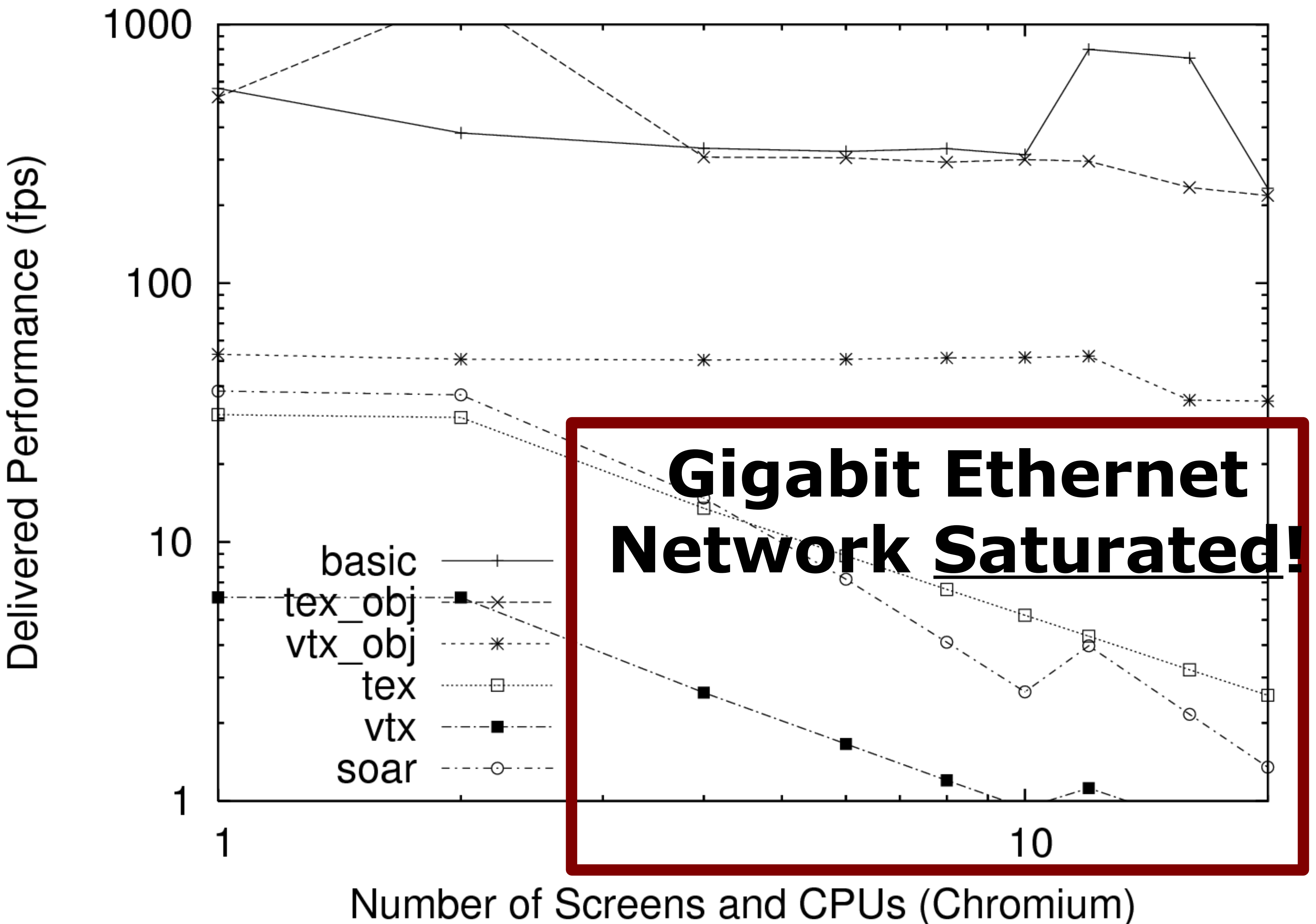
# MPIglut Performance



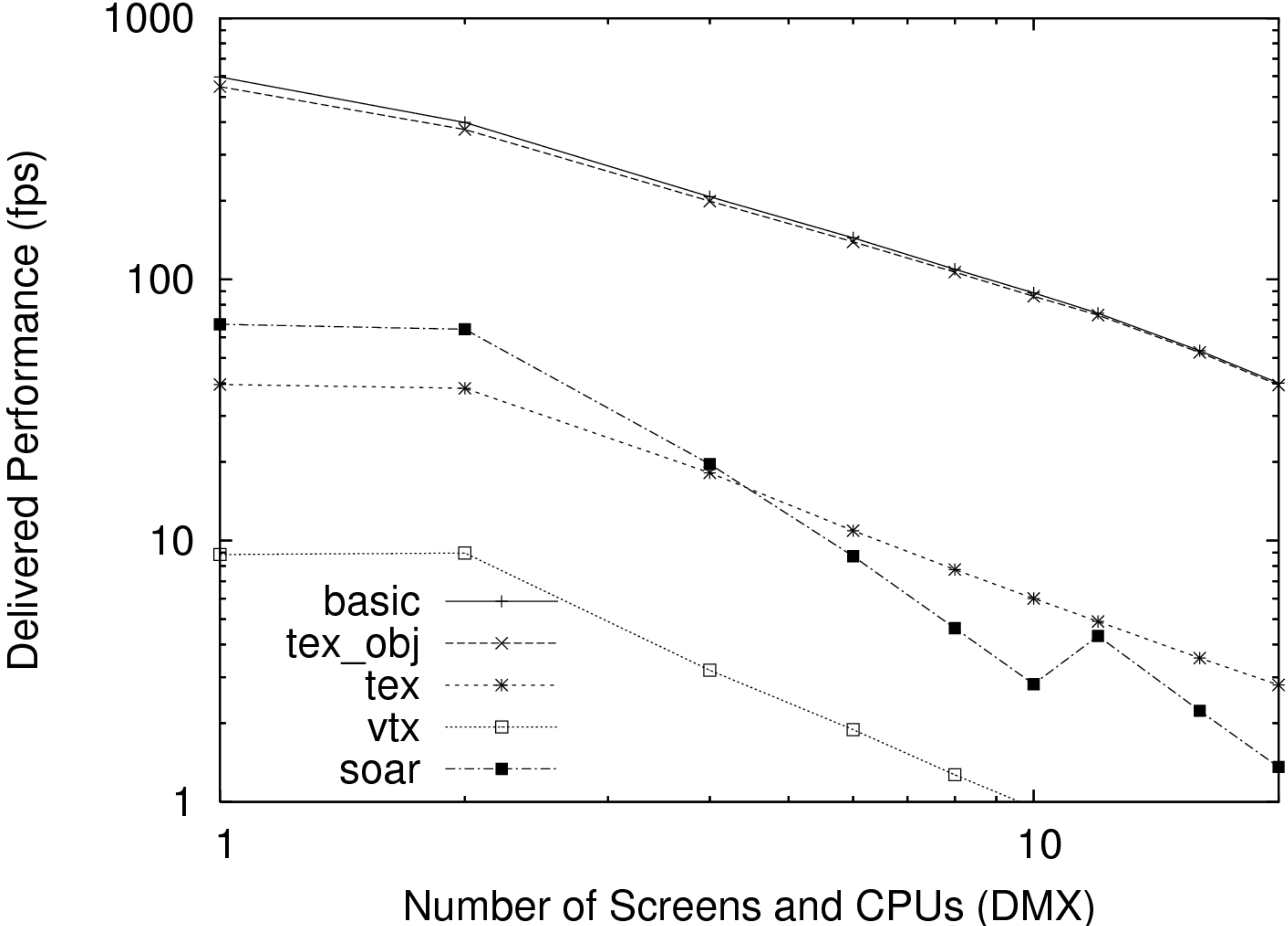
# Chromium Tilesort Performance



# Chromium Tilesort Performance



# DMX Performance

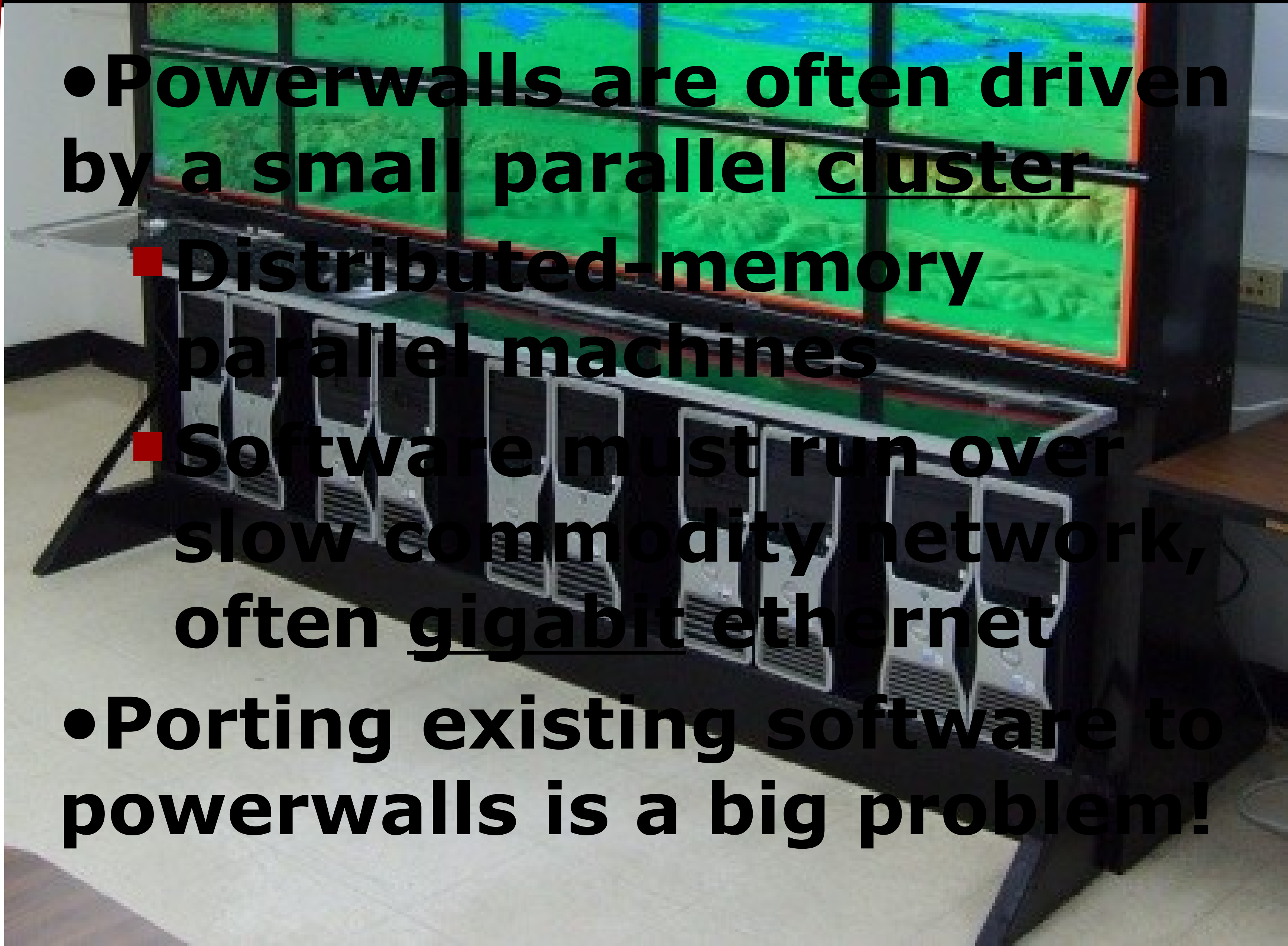


# Conclusion & Future Work

- **MPIglut: an easy route to high-performance parallel rendering**
- **Hiding parallelism inside a library is a broadly-applicable technique**
  - **THREADirectX? OpenMPQt?**
- **Still much work to do:**
  - **Multicore / multi-GPU support**
  - **Need better GPGPU support (tiles, ghost edges, load balancing)**
  - **Need load balancing, possibly by moving inter-processor boundaries**

# Backup Slides

# What is a "Powerwall"?



- Powerwalls are often driven by a small parallel cluster
  - Distributed-memory parallel machines
  - Software must run over slow commodity network, often gigabit ethernet
- Porting existing software to powerwalls is a big problem!