Virtual-Environment Research at the University of North Carolina at Chapel Hill

HMD

PIs: Fred Brooks, Henry Fuchs
Project Manager: Warren Robinett

Pixel-Planes

PIs: Henry Fuchs, John Poulton
Staff: John Eyles, Trey Greer, Laura Weaver

Tracking

Henry Fuchs, Jih-Fang Wang, Ron Azuma, Vern Chi, John Eyles, Gary Bishop

The Ultimate Display

— Ivan Sutherland, 1965 (Proc. of IFIP Congress):

"the task of the display is to serve as a looking-glass into the mathematical wonderland constructed in computer memory"

"the ultimate display would be a room within which the computer can control the existence of matter"

1968 (AFIPS Conference Proceedings):

reported first working virtual-environment system

Virtual-Environments at UNC

— building walk-through

— molecular modeling (and *haptic* displays)

— medical imaging

awaits: Pixel-Planes 5 real-time volume rendering
Medical 3D Ultrasound system (Duke)

Underlying Technologies

- computer image generation
  - high frame rate
  - realistic images
  - low latency
- tracking
  - 6 degrees of freedom
  - large working volume
  - update rate matching image generation with very low latency
- head-mounted display
  - comfortable
  - high resolution
  - preferably stereoscopic

Other Technologies

— human perceptual psychology

— real-time software

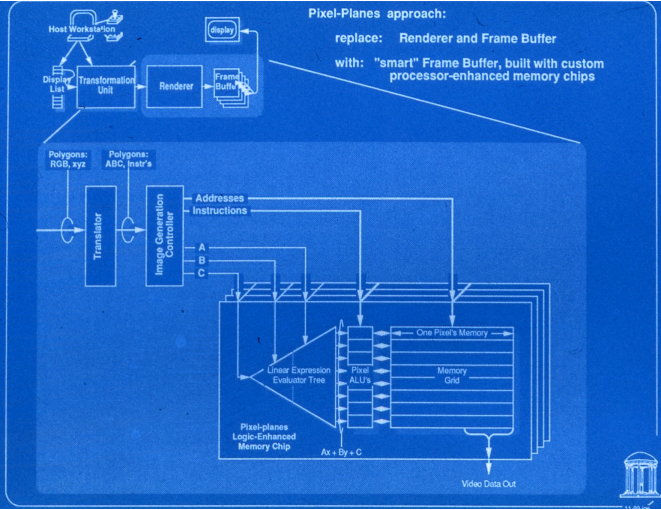
— difficult to study these while underlying hardware technologies are still so primitive

Image Generation

— most strongly driven by economic pressures

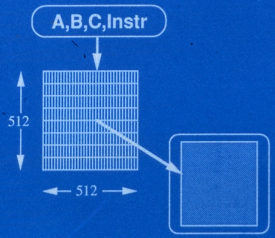
— numerous companies now producing systems with "real-time" performance

— still higher performance is required for real applications


Host Workstation
display
Display List
Transformation Unit
Renderer
Frame Buffer
Pixel-Planes approach:
replace: Renderer and Frame Buffer
with: "smart" Frame Buffer, built with custom processor-enhanced memory chips
Polygons: RGB, xyz
Polygons: ABC, instr's
Translator
Image Generation Controller
Addresses
Instructions
A
B
C
One Pixel's Memory
Linear Expression Evaluator Tree
Pixel ALU's
Memory Grid
Pixel-planes Logic-Enhanced Memory Chip
Ax + By + C
Video Data Out

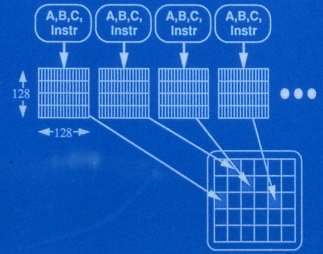
Pixel-Planes 4

A single, screen-sized computing surface locked 1:1 to screen pixels.



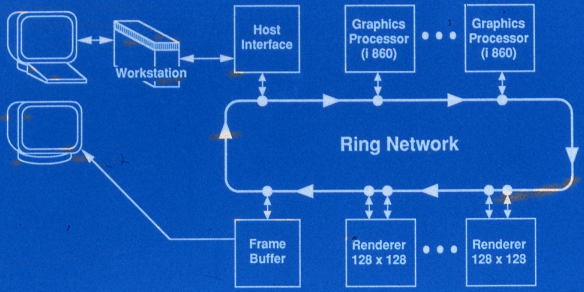
Pixel-Planes 5

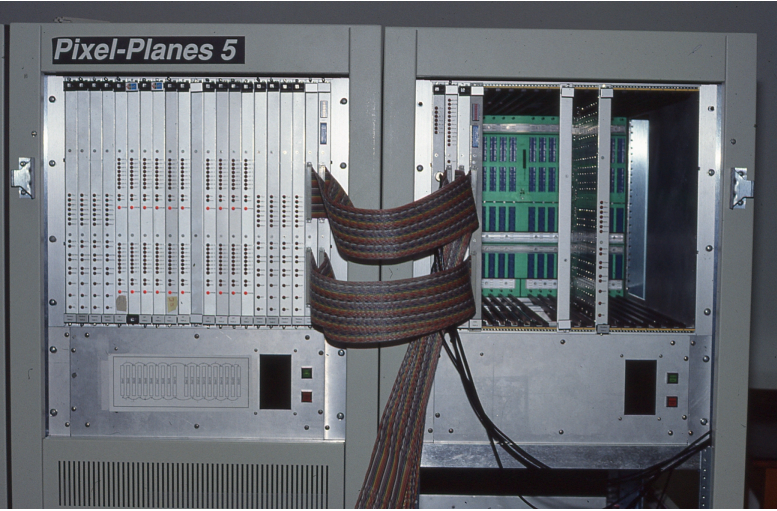
Multiple, small, independent computing surfaces flexibly mapped to the screen.



Potential: can increase performance linearly, simply by adding more Renderers.

Pixel-Planes 5




Pixel-Planes 5

Future Image Generation Work at UNC

— collaboration with Intel Scientific Computers: graphics accelerators for a supercomputer

— exploration of new approaches

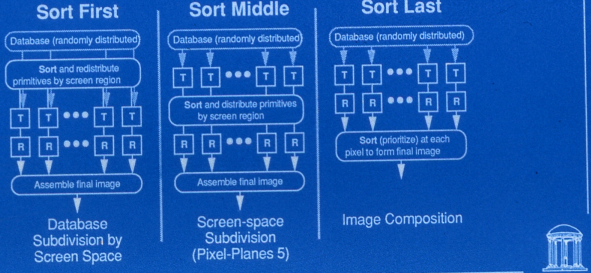
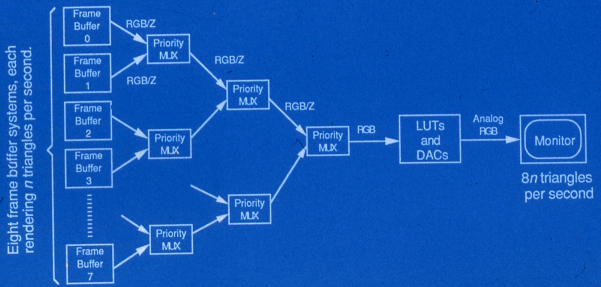


Image Composition

— "sort last" architecture (by Molnar and by Shaw)

— allows virtually unlimited performance increase with linear increase in hardware and negligible increase in latency



Tracking Requirements

- fast update (and low latency)
- high accuracy
  translational: fraction of a millimeter
  rotational: fraction of a degree
- large working volume: room-sized, or even outdoors !
- allow tracking more than one target (head and hand)
- compact, lightweight, comfortable, unrestrictive
- impose little restriction on environment

Tracking Today

— Polhemus is used by virtually everyone

— advantages
  does not require clear line of sight (like optical)
  easy to set up and lightweight

— disadvantages
  limited working volume (1 meter hemisphere)
  sensitivity to metal in environment (bends space)
  sensitivity to AC magnetic fields (jittering)
  slow update rate (long latency)

— some of these faults NOT inherent in magnetic approach

Tracking Approaches

— mechanical: used in Sutherland's first system
working range limited by mechanical linkage
difficult to track several objects

— acoustic (Lincoln Wand)
speed of sound limits update rate / working volume
air density variations affect accuracy

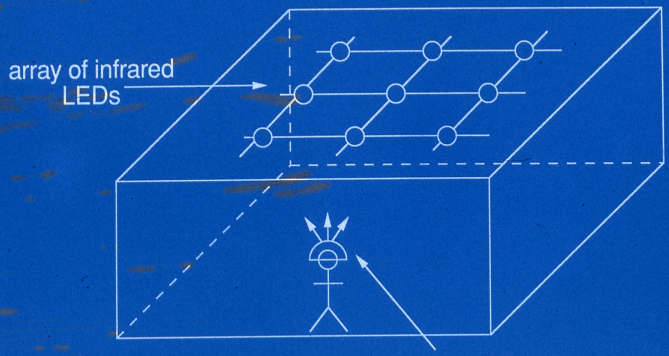
— magnetic (Polhemus, Ascension)
does not require clear line of sight
easy to set up and lightweight

— optical beacon trackers (Selspot, Optotrak)
require clear line of sight

Optical Inside-Out Tracking

- first suggested by Bishop et al. 1984
- beacons in environment / camera on user
- more sensitive to rotations
- cellular approach: working volume is infinitely and inexpensively extensible

Inside-Out Optical Tracker



Tracking: Future Work

— improve Inside-Out tracker with holographic optics

— eliminate need for optical beacons

silicon photo-sensors (Bishop's Self-Tracker)

— hybrid tracking schemes

fast low-stability inertial sensors
coupled with high-stability optical tracking

Display Hardware

— most early work by military

— virtual-environment has different requirements

— we're NOT in position to push technology of the actual displays

— we CAN prototype helmet structures and optical systems

— color displays have inherently low resolution

— Tektronix color shutter, beam penetration tubes, may allow some color with very high resolution

Experimental Philosophy

Any technology, including interactive computer graphics, advances fastest when coupled to real users and focused on a driving problem.

— Fred Brooks

— real users

— their primary interest is accomplishing some task

— their interest in computer graphics is secondary to their task