1. Introduction

1.1 Graphics Areas

- **Modeling**: building specification of shape and appearance properties that can be stored on the computer

- **Rendering**: creation of shaded images from 3D computer models

- **Animation**: to create an illusion of motion through sequences of images

Advantages

- **quantitative description** - precise, not easy to be recognized
- **Pictorial description** - easy to be recognized

History

Founded by the PhD thesis of Ivan D. Sutherland at MIT in 1963,

- A line drawing system with data structures for storing symbol hierarchies and interaction techniques

SIGGRAPH: important CG organization, formed in 1969

Website: [http://www.siggraph.org](http://www.siggraph.org)
1.2 Applications

Art, Entertainment, and Publishing
- Movie production, Animation, and Special Effects
- Computer Games
- Browsing on the World Wide Web
- Slide, Book and Magazine Design

Computer Graphics and Image Processing

Blending together more each year

Process Control (Monitoring)

Status display for refineries, power plants, computer networks from sensors attached to critical components

Simulation
- Flight simulation
- Simulation of the movement of a robot
- Simulation of ’virtual world’
Computer Aided Design (CAD)

- Computer Aided Mechanical Part Design (big market)
- Computer Aided Architectural Design
- Electrical Circuit (IC) Design

Scientific Analysis and Visualization

  Assist scientists in understanding measured data
  Provide insight into complex mathematical ideas

1.3 Elements of Pictures Created in Computer Graphics

Output Primitive:

- polylines
- text
- filled regions
- raster images
1.4 A Graphics System

Video Monitor:

Video Monitor:

- Electron gun
- Vertical deflection
- Control Grid
- Focusing System (Electron lens)
- Horizontal Deflection
- Electron beam
- Phospher coating
- Heating filament
- Cathode

Video Monitor:

- Input Devices: Keyboard, Tablet, Mouse
- Output Devices: Processor, Frame Buffer, Memory, Video Monitor

Video Monitor:
Control-grid voltage: control the picture’s intensity

Focusing system: force the electrons to converge

Deflection systems: to trace a picture on screen (most crucial part of the monitor)

Phospher: when struck by electron beams, most of the kinetic energy carried by the electrons is transferred to the electrons of the phospher atoms, so the electrons of the phospher atoms jump to a higher quantum energy levels. These excited electrons return to their previous quantum levels by giving up their extra energy in the form of light at frequency depicted by the quantum theory
**Persistence:** the time from the removal of excitation to the moment when phosphorsense decayed to 10% of the initial light output

**Refresh rate:** number of times per second a picture is redrawn (determined by persistence)

**Fusion frequency:** the refresh rate above which a picture stops flickering and fuses into a steady picture

**Note:**
1. Refresh rate for raster scan display is fixed (30 to 60), independent of the picture complexity

2. Highly dynamic applications need low-persistence phosphor. CAD applications tend to use long-persistence phosphor.

3. The relationship between fusion frequency and persistence is nonlinear.
1.5 Display processing Unit:

A simple two-color raster-scan system
Image Storage System (frame buffer, bitmap):

- refresh memory arranged as a 2D array; each entry corresponds to a screen pixel

- each entry is composed of a number of bits; brightness and/or color value of each pixel of the screen is stored in corresponding entry in frame buffer

- implemented with solid state RAM

Image Display System (video/image controller):

- cycle through frame buffer row by row, 30 or 60 times/sec

- memory reference addresses are generated in synchronism with the raster scan; contents of the memory are used to control monitor beam’s intensity

- changes in frame buffer is done during the 1.3 millisecond flyback (or, vertical retrace) time

- interlaced raster scan (to produce a picture whose effective refresh rate is closer to 60 than to 30 Hz.

Image Creation System:

- scan convert abstract representation of an image into appropriate pixel values in the frame buffer
1.6 Shadow Mask Color Monitor

- phospher dots (red, green, blue) are arranged in triangular pattern called triad (or, pixel)
- three electron guns are used
- a shadow mask, behind the view surface, is equipped so that each small hole for each triad (holes are aligned so that each electron gun excites its corresponding phospher dot)
- resolution of these monitors is limited
  (high resolution: triads are on about .21mm centers)
  (home TV: triads are on about .60mm centers)
1.7 Display with Lookup Table (LUT)

- each number stored in frame buffer is an index (address) into a lookup table (color table or color map)

- Lookup table provides significant saving on memory while gives the ability to change colors from picture to picture
1.8 Flat-Panel Displays

- Liquid-crystal display (LCD)
- Active matrix panel (AMP)
- Plasma panel

Liquid-crystal display (LCD):

- Six layers (see the above figure)
- Liquid-crystal is made up of long crystalline molecules arranged in a spiral fashion
- Direction of polarization of polarized light passing through is rotated 90°
- The crystals line up in the same direction when in an electric field, therefore no polarizing effect
- In this case the light passing through the liquid-crystal layer will be absorbed by the rear polarizer, so the viewer sees a dark spot on the display

- To create a dark spot at \((x_1, y_1)\), use *matrix addressing*: applying a negative voltage \(-V\) to the vertical grid wire \(x_1\) and a positive voltage \(+V\) to the horizontal grid wire \(y_1\) to create an electric field at \((x_1, y_1)\).

- To display dots at \((x_1, y_1)\) and \((x_2, y_2)\), cannot simply apply negative voltage to \(x_1\) and \(x_2\) and positive voltage to \(y_1\) and \(y_2\): that would cause dots to appear at \((x_1, y_1)\), \((x_2, y_2)\), \((x_3, y_3)\) and \((x_4, y_4)\). We have to activate them one at a time. The display is refreshed one row at a time.

**Active Matrix Panel:**

- LCD panel with a transistor at each grid point
- Transistor can hold the cell in "adjusted" state until changed
- The display need not be refreshed and is brighter

**Plasma Panel:**

- Similar to the center part of the previous figure
- Array of tiny neon bulbs
- Need not be refreshed
### 1.9 Input Devices

#### 1.9.1 Logical Classes of devices and techniques

<table>
<thead>
<tr>
<th>Logical Device</th>
<th>Function</th>
<th>Prototype (Physical device)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Keyboard (string)</td>
<td>Input a character string</td>
<td>alphanumeric keyboard</td>
</tr>
<tr>
<td>Locator</td>
<td>Indicate a position and/or orientation</td>
<td>Tablet, mouse, joystick</td>
</tr>
<tr>
<td>Pick</td>
<td>Select a displayed entity</td>
<td>Light pen</td>
</tr>
<tr>
<td>Choice</td>
<td>Select from a set of actions or choices</td>
<td>PFK, mouse</td>
</tr>
<tr>
<td>Dial (Valuator)</td>
<td>Input an analog value (number)</td>
<td>Slidebar, potentiometer</td>
</tr>
</tbody>
</table>
1.9.2 Physical Input Devices

**Keyboard:**
- each keystroke causes a 7-bit code (ASCII, EBCDIC, etc) to be stored in a character register, the CPU is interrupted
- the interpretation of the code is determined by the CPU program
- characters might be accumulated into a buffer until a terminating character is typed, thereby giving the application program a character string input device

**Tablet:**
- A flat surface and a stylus or hand cursor
- electrical sensing mechanism is used to measure the stylus or cursor position (within half inch of the tablet surface)
- downward pressure on the stylus closes a microswitch (pressure-sensitive switch) and interrupts the computer
- particular handy for digitizing drawings
**Mouse**: most commonly used

- using mechanical detector or optical detector to measure motion

- mechanical mice measure distance by turning a ball (at the bottom) and consequently a pair of encoders. The encoders measure motion in two directions.

- optical mice measure distance traveled by counting lines on a special pad

- a relative device, has no absolute origin, report only changes from their former position

- can be used to specify an arbitrarily large change in position

- the application program can reposition the cursor anywhere on the screen
Light pen:

- the pen sees the sharp burst of fluorescent light emitted when the electron beam is actually bombarding the phosphor, not sensitive to the more prolonged phosphorescence or to ambient room light
- pen’s output connected to image display system (IDS); when IDS is interrupted, it sends CPU the contents of the \( X \) and \( Y \) registers which are the \( x \) and \( y \) coordinates of the pixel detected (hence, on a raster-scan display, light pen implements a locator)
- popularity of light pens will decrease in the future
**Valuator**: (prototype: potentiometer)

- can be rotary or slide potentiometers (slide bars)
  (e.g., volume, balance, and tone controls on a stereo set)

To power supply
Positive voltage $V$

Voltage = $V$

Potentiometer slider
moved by user

Analog to digital converter

DPU Register

CPU

Voltage = $V_1$

Voltage = 0

Ground

- by rotating the dial (for rotary potentiometer) or moving the slider (for slide potentiometer), scalar can be generated and placed in DPU device registers and then read by CPU
1.10 Input Modes

- Defined by the relationship between the measure process and the trigger
  Measure: what the device returns to the user program
  Trigger: a physical input on the device

- The display processing unit contains a number of registers (buffers). Once initialized, input devices store appropriate values in these registers

**Request mode:** The measure of the device is not returned until the device is triggered

**Sample mode:** Input provides immediate input
  No trigger is needed

**Event mode:** when a device is triggered, the device measure with the identifier for the device is placed in an "event queue"
  (but application program is not interrupted)
1.11 Clients and Servers

Primary motivation for the development of X Window System:

"do graphics over a network"

In a world of distributed computing and networks, building blocks are entities called "server"

\[
\begin{array}{ccc}
\text{Print Server} & \text{Client} & \text{Client} \\
\downarrow & \uparrow & \uparrow \\
\uparrow & \downarrow & \downarrow \\
\text{File Server} & \text{Compute Server} & \text{Client}
\end{array}
\]

Server: remote machine supporting client workstations

However, for X Window System

Server: device that displays the graphics
  (machine in front of the user)

Client: device that does computation
  (whatever machine running the application)
**Concept of X Server**

Then (Vector Display Device):

Now