Overview Lecture 2

- Primitives and Attributes
- Why Scan Conversion?
- Algorithms for
  - Scan Conversion
  - Lines
  - Circles
  - Ellipses
  - Filling
  - Polygons

2D Output Prmitives and Attributes

PRIMITIVES

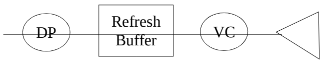
- Points
- Lines
- Circles
- Ellipses
- Curves
- Filled Area
- Text

ATTRIBUTES

- Line Type, Width and Color
- Fill Styles: Hollow, Solid and Patterned
- Text Font, Color, Size and Style

Text
Text
Text
Text

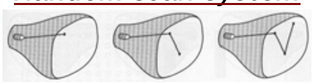
Raster Scan System

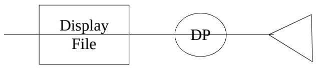


Advantages
Realistic Shading
No Flickering

Disadvantages
Aliasing
Scan Conversion

Random Scan System



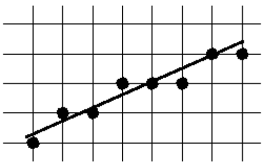


Advantages
Light Pen Pick
Built-in Lines

Disadvantages
Flickering
No Realistic Shading
Programming more difficult

Scan Conversion

- **Problem:**
  - To represent a perfect image as a bitmapped image.
- **We want:**
  - Fast algorithms.
  - Incremental algorithms.
  - Avoid floating point.



Line Drawing Algorithms

- Lines are used a lot - want to get them right.
- Lines should appear straight, not jagged.
  - Horiz., vert. and diagonal easy, others difficult
- Lines should terminate accurately.
- Lines should have constant density.
- Line density should be independent of line length or angle.
- Lines should be drawn rapidly.
  - Efficient algorithms.

DDA (Digital Differential Analyzer) Algorithm

- Faster than brute force.
- Based on Calculating either Δx or Δy.
- Mathematically well defined.

- Floating point.
- Round off error.
- Time consuming arithmetic.

DDA Line Drawing Algorithm

```
LineDDA(int x0, int y0,
        int xl, int  yl) {
    int dx,dy,steps,k;
    float xinc,yinc,x,y;
    dx = x1-x0;   dy = y1-y0;
    if (as(dx) > abs(dy))
        steps = abs(dx);
    else
        steps = abs(dy);

    xinc = dx/steps;
    yinc = dy/steps;
    x = x0;   y = y0;
    DrawPixel(round(x, round(y));
    for (k = 1; k <= steps; k++) {
        x = x + xinc;
        y = y + yinx;
        DrawPixel(round(x),
                  round(y));
    }
}
```

Bresenhams Line Algorithm

- Accurate
- Efficient
- Integer Calculations
- Uses Symmetry
- Adapted to display circles, ellipses and curves.

- Cannot generalize to arbitrary conics. Thus, use Midpoint Line Algorithm.
- It has been proven that the algorithm gives an optimal fit for lines.

Midpoint Line Algorithm

- **Midpoint:** Looks at which side of the line the midpoint falls on.
- **Bresenham:** Looks at sign of scaled difference in errors.
- It has been proven that Midpoint is equivalent to Bresenhams for lines.

Bresenhams Line Drawing Algorithm

1. Input the two line endpoints. Store the left endpoint (x_0,y_0).
2. Plot the first point (x_0,y_0).
3. Calculate constants Δx, Δy, and $2\Delta y - 2\Delta x$ and $2\Delta y$. Get starting values for decision parameter p_k.

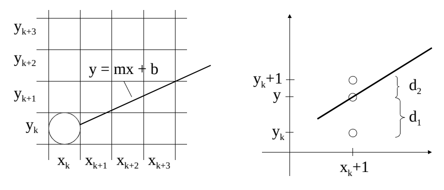
   $P_0 = 2\Delta y - \Delta x$
4. At each x_k along the line, starting at k = 0, do the following test: if $p_k < 0$, the next point to plot is $(x_k + 1, y_k)$ and

   $p_k+1 = p_k + 2\Delta y$

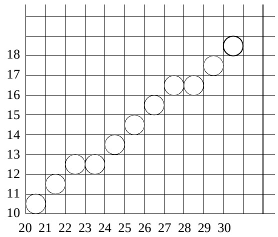
   else, the next point to plot is $(x_k + 1, y_k + 1)$ and

   $p_k+1 = p_k + 2\Delta y - 2\Delta x$
5. Repeat step 4 Δx times.

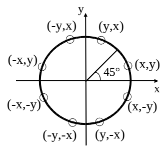
Bresenhams Line Drawing Algorithm

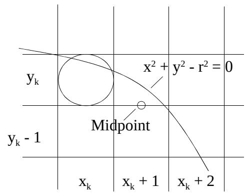


Bresenhams Line Drawing Algorithm

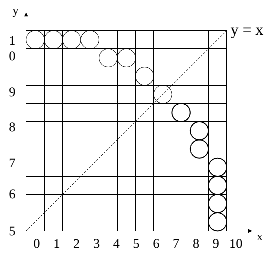


Midpoint Circle Algorithm

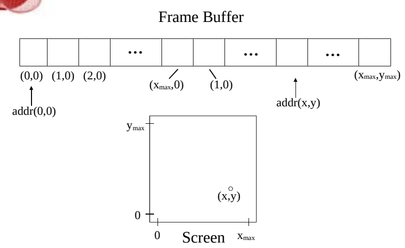




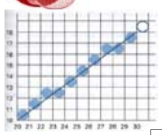
Midpoint Circle Algorithm



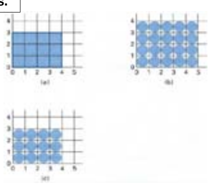
Loading the Frame Buffer



Maintaining Geometric Properties

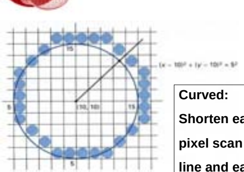


Lines:
Omit one of the end point pixels.

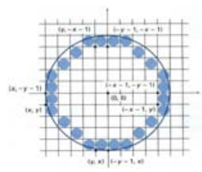


Fill:
Use only pixels "interior" to the object boundaries.

Maintaing Geometric Properties



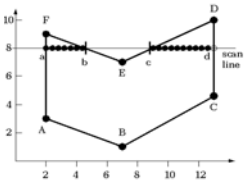
Curved:
Shorten each pixel scan line and each pixel column.



Scan Conversion of Polygons

Problem:

- Two line segments that share the same pixel.
- Determine which pixels on each scan line are within the polygon.



Scan Conversion of Polygons

Incremental polygon fill for each scan line:

- Find all the polygon edges the scan line intersects.
- Sort the intersections by increasing x coordinate.
- Fill all pixels between inter-sections that are interior to the polygon by using the *odd-parity-rule*.

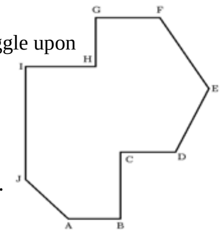
Scan Conversion of Polygons

Odd-parity-rule:

- Start with even parity and toggle upon encountering each edge.
- Draw when parity is odd.

Remember:

- y_{min} counts, but y_{max} does not.
- Horizontal lines do not count.



Overview

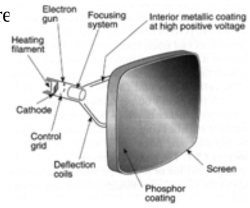
- Display Technology
  - CRT
  - LCD
- Input Devices
- Output Devices
- Raster Scan Display System

Overview - CRT Display Technology

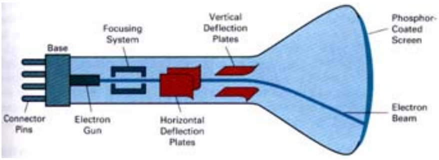
- CRT (Cathode-Ray Tube)
- Difficulties with the CRT
- Refresh Rate
- Persistence
- Critical Fusion Frequency (CFF)
- Color CRT - Raster Scan
  - Shadow Mask
    - Delta-Delta CRT
    - Precision In-Line CRT

Cathode Ray Tube (CRT)

- Most common design in display devices
- The main components are
  - Electron gun
  - Focusing system
  - Deflection coils
  - Phosphor coated screen

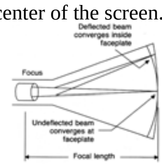


Cathode Ray Tube (CRT)



Difficulties with the CRT

- Sometimes the convergence point is behind the screen.
  - The picture appears to be blurred.
- The beam is in focus at the center of the screen.
  - Dynamic focusing.

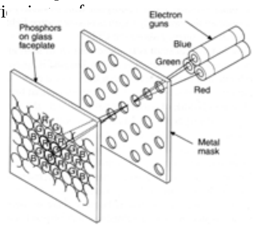


Display Technology

- Refresh rate:
  - The screen must be updated about 50-60 times per second for raster display.
  - Not dependent on the complexity of the picture.
- Persistence:
  - The time it takes the emitted light from the screen to decay 10% of its original intensity.
- Critical fusion frequency (CFF):
  - The frequency rate when flickering stops and the image become steady.
  - The relation ship between CFF and persistence is non-linear.

Color CRT - Raster Scan

- **Shadow Masks** - a thin metal plate with small holes mounted close to the vi
- Delta-Delta CRT
  - Electron guns and phosphor dots are arranged in a triangular triad pattern.
- Precision in-line CRT
  - Electron guns and phosphor dots are in a line.

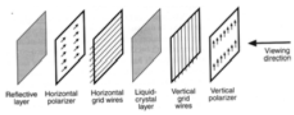


Color CRT - Raster Scan

- Resolution is limited to the hole size of the shadow-mask.
  - Smaller holes - better resolution.
- The inside surface of the screen is covered with red, green and blue phosphor dots.

Liquid Crystal Display (LCD)

- Made up of six layers:
  - Two polarizers (vertical and horizontal)
  - Two thin grid wires (horizontal and vertical)
  - One layer of liquid crystal
  - One reflective layer



Liquid Crystal Display (LCD)

Passive Matrix

- Display is refreshed in raster-scan fashion (row-by-row).

Active matrix is
- brighter,
- more colorful and
- faster than

passive matrix.

Active Matrix

- Transistors at each (x,y)
  → can change on/off state quickly.
- No refresh is needed (unless image is changed).
- The dominant technology used in LCD's today.

LCD vs. CRT

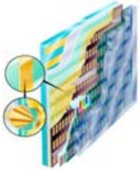
- Three times brighter.
- Five times more contrast.
- TFT technology more efficient.
- Uses less electricity.
- Takes less space.
- Emits less radiation.
- Distortion free viewing.
- No flickering.
- Digital output.
- Improved active matrix mat.

- Narrow viewing angle.
- Resolution.
- Price.

Field Emission Display (FED)

Take the best of both CRT and LCD.

CRT
- Good color.
- High resolution.
- Fast response time.
- Wide view angle.



LCD
- Small package size.
- Low weight.
- Low power consumption.

High performance phosphor + low power electronic

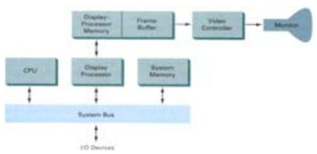
Input Devices

- Have improved greatly over the years.
- The primary means for creating images on a computer graphics system
  - Keyboards
  - Trackball
  - Spaceball
  - Data Glove
  - Image Scanners
  - Light Pens
  - Mouse
  - Joysticks
  - Digitizers
  - Touch Panels
  - Voice Systems

Output Devices

Raster Display System

- Raster display system with dedicated display processor and memory.



Video Controller - Raster Display

- Constantly refreshing the display.
- Often includes a look-up table.
- Interlaced or non-interlaced.