2D Graphics

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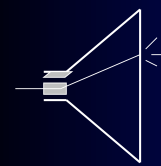
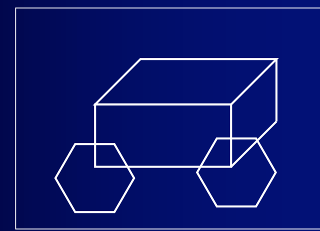
Based on "Tricks of the Game-Programming Gurus" pp.72-109

Lots of obvious observations that make drawing easy

Vector Graphics



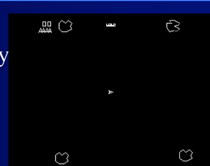
Directly control electronic gun of CRT



•Drawings defined as lines
•Lines stored as endpoints
•Look like wireframes
•No curved lines
•Limited variation in color or intensity.

History of 2D graphics: Vector

- Example: Asteroids, Battlezone
  - http://www.squadron13.com/games/asteroids/asteroids.htm
- Advantages:
  - Control the electronic gun directly
  - Only draw what is on the screen
  - No jagged lines (aliasing).
  - Only store endpoints of lines



- Problems:
  - Best for wireframes.
  - Must draw everything as lines: text, circles,
  - $$'s: Can't use commercial TV technology
- Example Displays:
  - Textronics, GDP

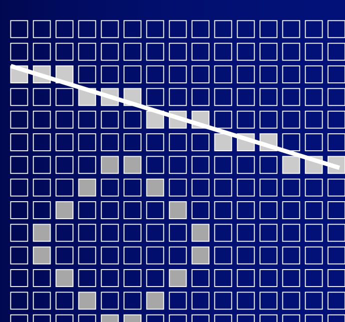
Raster Graphics

- Advantages:
  - Cheaper
  - Can easily draw solid surfaces
  - Maps screen onto 2D memory
  - Can move blocks of image around, control individual pixels
- Problems:
  - Memory intensive
  - Aliasing problems
- Example:
  - VGA =
    - 640 x 350 with 16 colors
    - 320x200 with 256 colors

Raster Graphics

Screen is made up of "picture elements" = pixels.

Color defined by mixture of 3-guns: Red, Green, Blue

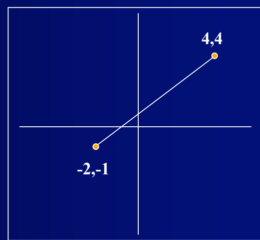


Current Approach

- Use Raster Graphics as underlying technology
  - Memory is cheap
  - Get access is every point on the screen
- Create drawing primitives similar to those in vector graphics
  - Drawing lines
- Support surfaces, textures, sprites, fonts, etc. directly
- Sprites vs. Graphics??

2D Graphics

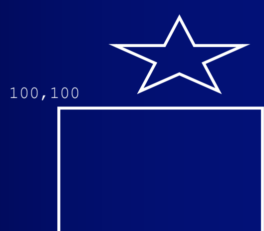
- Points
  - x,y
- Lines
  - Two points
  - Draw by drawing all points in between
  - Low-level support for this in hardware or software



Coordinate System

Polygons

- Defined by vertices
- Closed: all lines connected
- Draw one line at a time
- Can be concave or convex
- Basis for many games

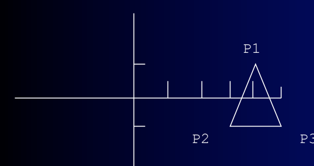


- Required data:
  - Number of vertices
  - Color
  - Position: x, y
  - List of vertices
    - Might be array with reasonable max

```
moveto(100,100)
lineto(100,300)
lineto(500,300)
lineto(500,100)
lineto(100,100)
```

Positioning an object

- Problem: If we move an object, do we need to change the values of every vertex?
- Solution:
  - *World* coordinate system for objects
    - coordinates relative to screen
  - *Local* coordinate system for points in object
    - coordinates relative to the position of the object

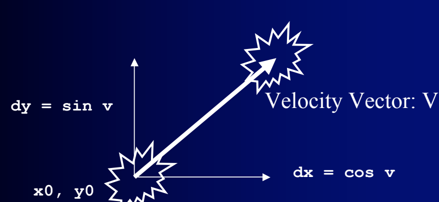


Triangle location: 4,0

```
P1:  0,  1
P2: -1, -1
P3:  1, -1
```

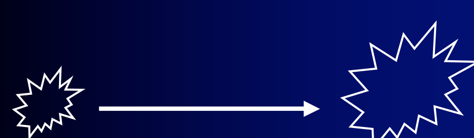
Translation: Moving an Object

- To move an object, just add in changes to position:
  - xo = xo + *dx*
  - yo = yo + *dy*
- If have motion, the *dx* and *dy* are the x and y components of the velocity vector.



Scaling: Changing Size

- Multiply the coordinates of each vertex by the scaling factor.
- Everything just expands from the center.
- `object[v1].x = object[v1].x * scale`
- `object[v1].y = object[v1].y * scale`



Rotation: Turning an object

- Spin object around its center in the z-axis.
- Rotate each point the same angle
  - Positive angles are clockwise
  - Negative angles are counterclockwise
- `new_x = x * cos(angle) - y * sin(angle)`
- `new_y = y * cos(angle) + x * sin(angle)`
- Remember, C++ uses radians not degrees!

Matrix Operations

- Translation, rotation, scaling can all be collapsed into matrix operations:
- Translation: | x y 1 | *

1	0	0
0	1	0
dx	dy	1

- Scaling: sx, sy = scaling values

sx	0	0
0	sy	0
0	0	1

- Rotation:

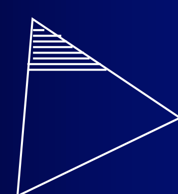
cos	-sin	0
sin	cos	0
0	0	1

Putting it all together

sx*cos	-sx*sin	0
sy*sin	sy*cos	0
dx	dy	1

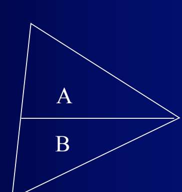
Filling in a Triangle: Rasterization

- Many system draw 3D objects as collections of triangles -- not arbitrary polygons
- If we can fill a triangle, that is pretty good.
- General idea: draw horizontal lines to fill it in.
- All done in hardware
- Example:



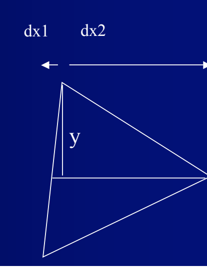
Fill: Step 1

- Split triangle into two parts:
  - One flat top
  - One flat bottom
- Gives single slope changes in x as we move vertically



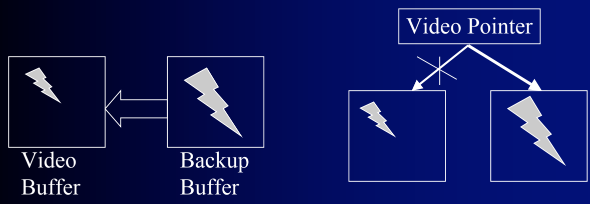
Step 2 & 3

- For triangle A, pre-calculate dx1/y and dx2/y based on slopes of edges.
  - Initial x1 and x2 to x value of vertex.
- Start at top and loop through until y = 0
  - Drawing lines from x1 to x2.
  - Decrement y each time.
  - Subtract dx1/y from x1.
  - Add dx2/y to x2.
- Inverse for triangle B



Common Problems: Flicker

- Too slow updating
- Change video buffer during updating.
- Solution:
  - Double buffering -- write to a “virtual screen” that isn’t being displayed.
  - Either BLT buffer all at once, or switch pointer.



Speed Issues (Gone)

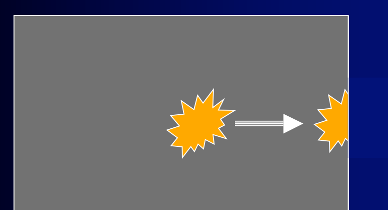
- Using regular drawing routines
  - Original Microsoft graphics library (GDI) was quite slow
  - Not a problem now – DirectX is ok
- Using Floating Point
  - Floating point used to be much slower than integer
  - Not a problem with Pentium architecture
- Using Standard Trig functions
  - Current machines are fast enough
  - If you start having performance problems, pre-compute and store all rotations you are going to need

Image Space vs. Object Space

- Image space:
  - What is going to be displayed
  - Primitives are pixels
  - Operations related to number of pixels
    - Bad when must to in software
    - Good if can do in parallel in hardware – have one “processor”/pixel
- Object space:
  - Objects being simulated in games
  - Primitives are objects or polygons
  - Operations related to number of objects

Clipping

- Display the parts of the objects on the screen.
  - Can get array errors, etc. if not careful.
  - Easy for sprites – done in DirectX
- Approaches:
  - Border vs. image space or object space



Border Clipping

- Create a border that is as wide as widest object
  - Only render image
  - Restricted to screen/rectangle clipping
  - Still have to detect when object is all gone
  - Requires significantly more memory

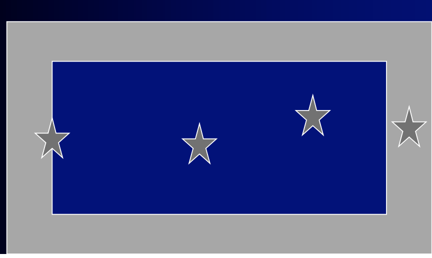
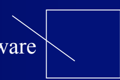


Image Space Clipping

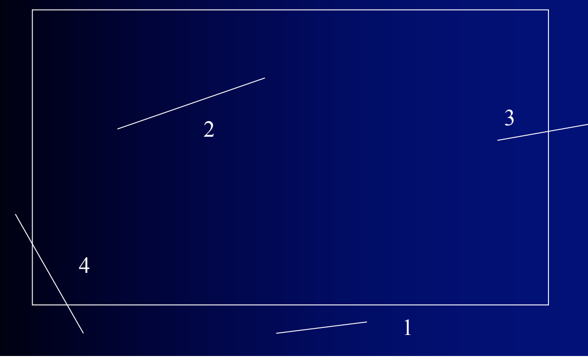
- Image Space:
  - The pixel-level representation of the complete image.
- Clipping
  - For each point, test if it is in the region that can be drawn before trying to draw it
  - If buffer is 320x200, test 0-319 in x, 0-199 in y.
- Evaluation
  - Easy to implement
  - Works for all objects: lines, pixels, squares, bit maps
  - Works for subregions
  - Expensive! Requires overhead for every point rendered if done in software.
  - Cheap if done in hardware (well the hardware cost something).

Object Space Clipping

- Object space:
  - Representation of lines, polygons, etc.
- Clipping
  - Change object to one that doesn't need to be clipped
  - New object is passed to render engine without any testing for clipping
- Evaluation
  - Usually more efficient than image space software
    - But hardware support of image space is fast
  - Need different algorithm for different types of objects
    - Lines are easy. Concave objects are problematic
    - Usually just worry about bitmaps

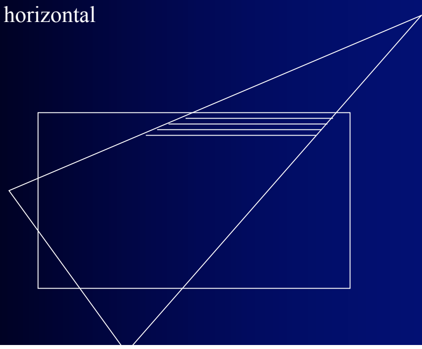


Line Clipping Cases



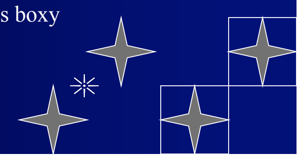
Clipping Filled Triangles

- Do this in image space during rasterization
  - Add tests so throw out whole lines – easier because they are all horizontal

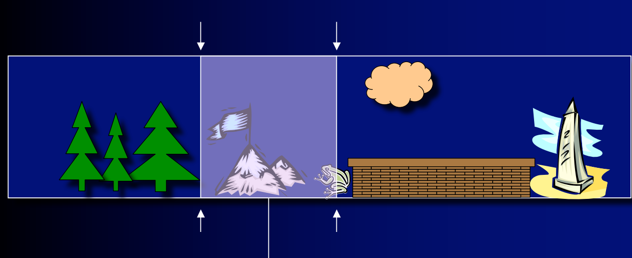


Collision Detection

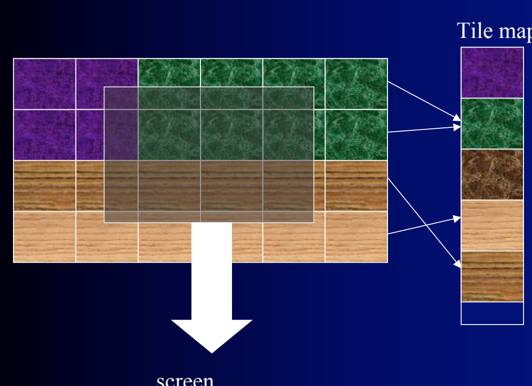
- Image Space:
  - Pixel by pixel basis. Expensive.
- Object Space:
  - Hard for complex and concave spaces:
- Standard Approach:
  - Cheat!
  - Create a bounding box or circle
    - test each vertex to see in another object
  - Hide this by making your objects boxy
  - Don't have objects like:



Scrolling - simple



Scrolling – Tile Based



Scrolling – Sparse

- Object-based
  - Keep list of objects with their positions
  - Each time render those objects in current view
  - Go through list of object – linear in # of objects
- Grid-based
  - Overlay grid with each cell having a list of objects
  - Only consider objects in cells that are in view