2D Graphics

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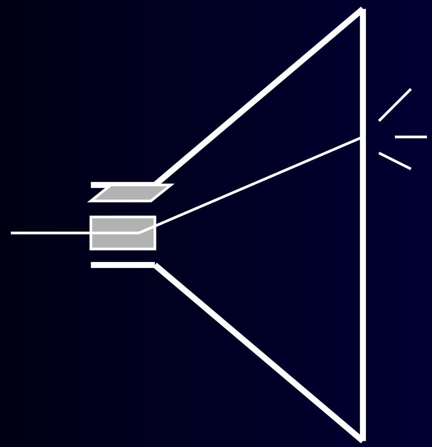
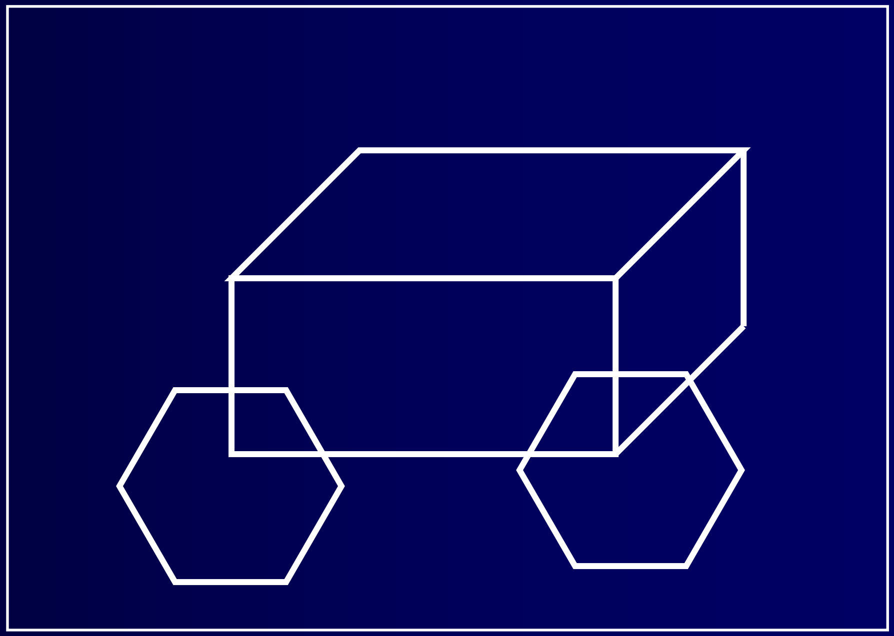
Based on "Tricks of the Game-Programming Gurus" pp.72-109

Lots of obvious observations that make drawing easy

Vector Graphics



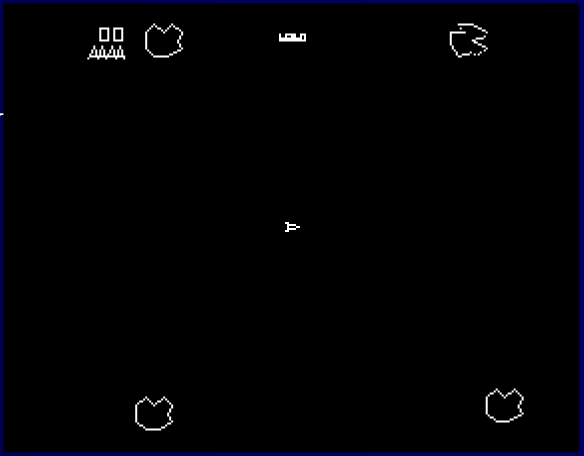
Directly control
electronic gun of CRT



- 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

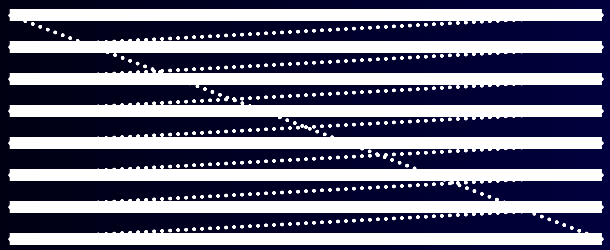


- Problems:
  - Best for wireframes.
  - Must draw everything as lines: text, circles,
  - $$'s: Can't use commercial TV technology
- Example Displays:
  - Textronics, GDP

Raster Graphics

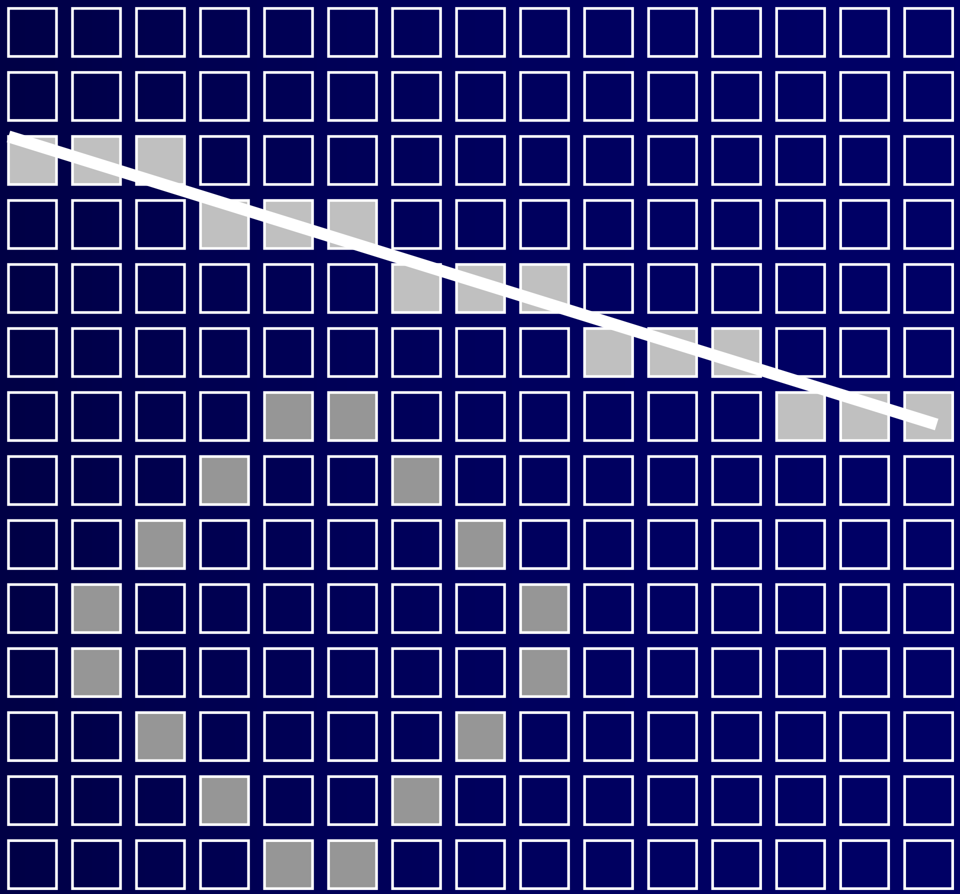
- Advantages:
  - Cheaper
  - Can easily draw solid surfaces
  - Maps screen onto 2D memory
  - Can move blocks of image around, control individual pixels
- Problems:
  - Memory intensive
  - Aliasing problems
- Example:
  - VGA =
    - 640 x 350 with 16 colors
    - 320x200 with 256 colors

Raster Graphics



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

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



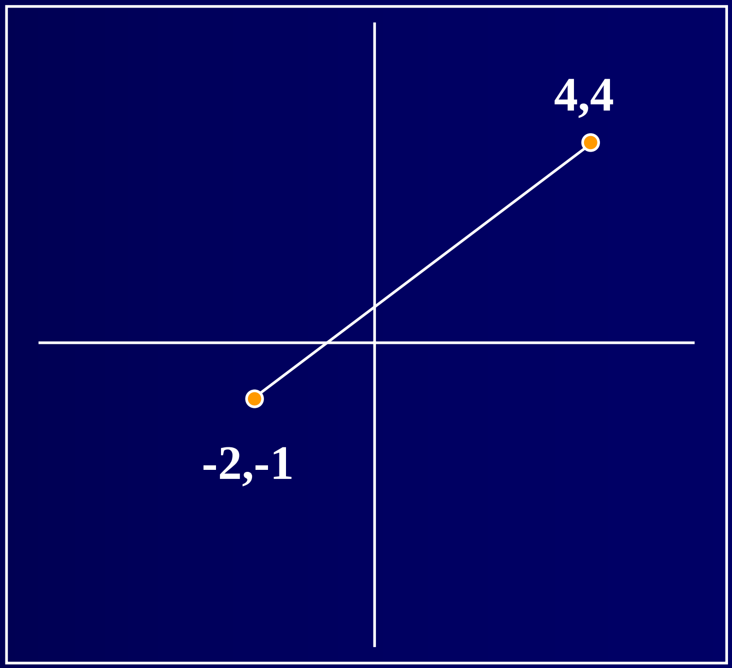
Current Approach

- 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

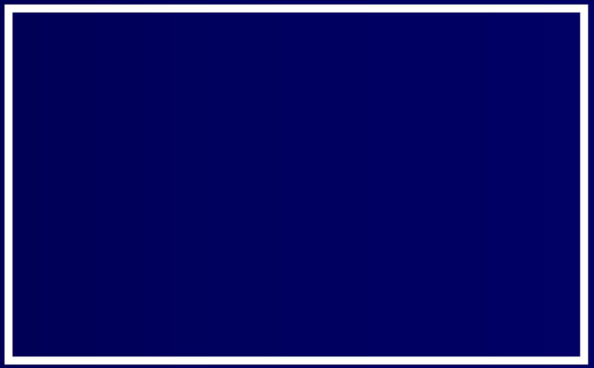


Coordinate System

Polygons

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

100,100

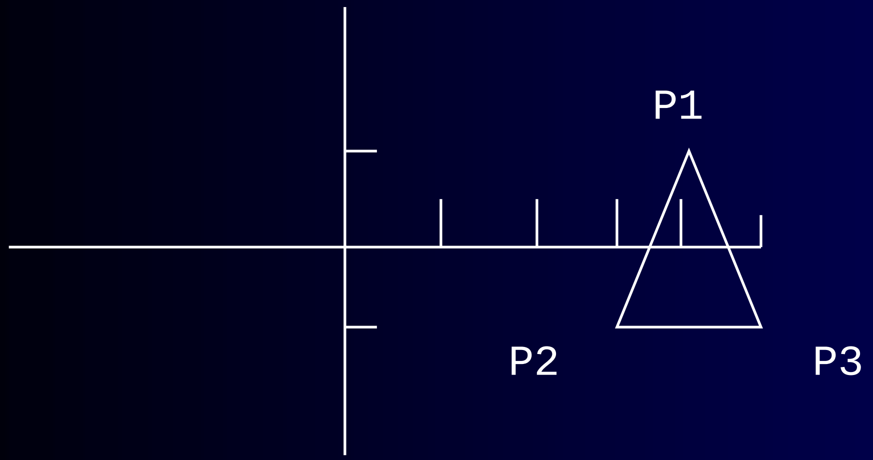


- Required data:
  - Number of vertices
  - Color
  - Position: x, y
  - List of vertices
    - Might be array with reasonable max

```
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

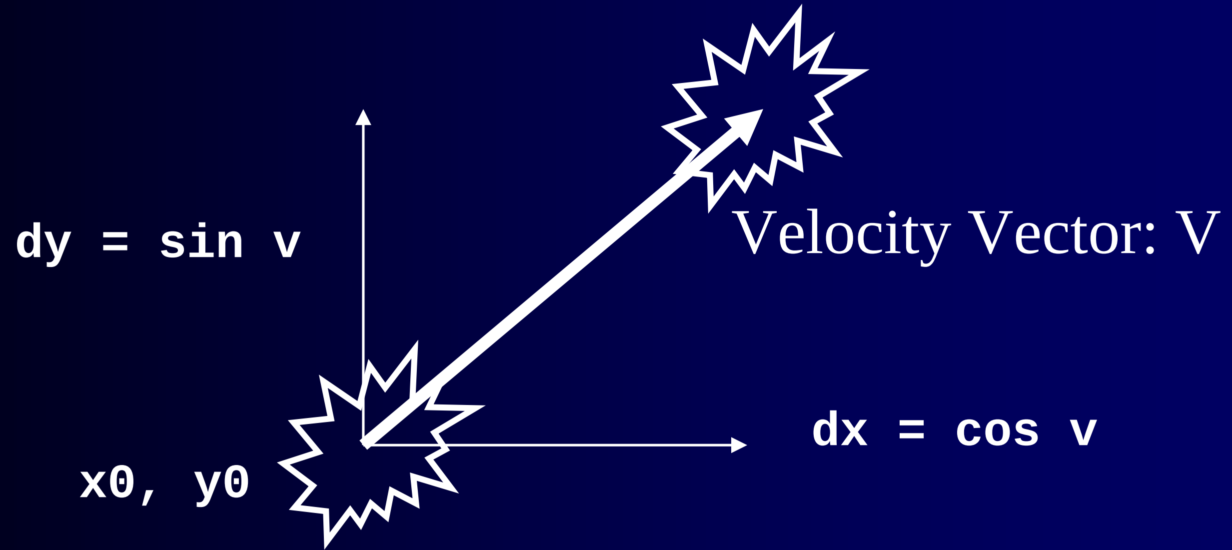


Triangle location: 4,0

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

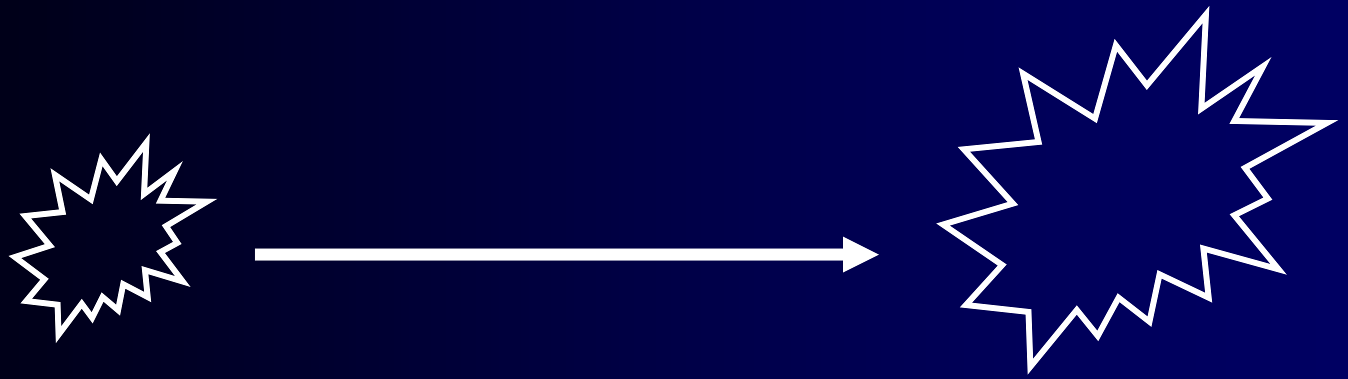
Translation: Moving an Object

- 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:

$$\begin{vmatrix} x & y & 1 \end{vmatrix} * \begin{vmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ dx & dy & 1 \end{vmatrix}$$

- Scaling: `sx, sy = scaling values`

$$\begin{vmatrix} sx & 0 & 0 \\ 0 & sy & 0 \\ 0 & 0 & 1 \end{vmatrix}$$

- Rotation:

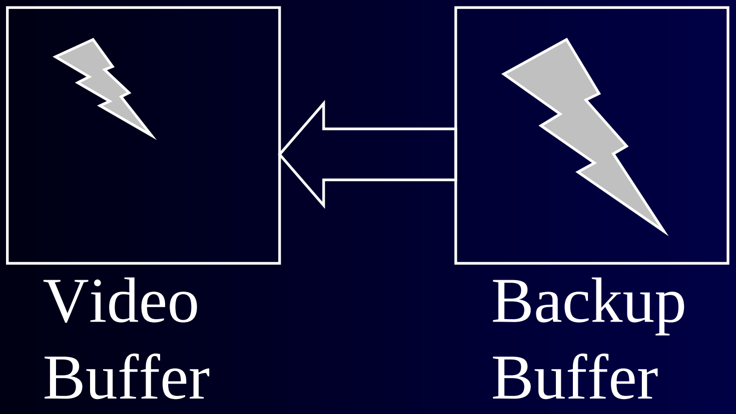
$$\begin{vmatrix} \cos & -\sin & 0 \\ \sin & \cos & 0 \\ 0 & 0 & 1 \end{vmatrix}$$

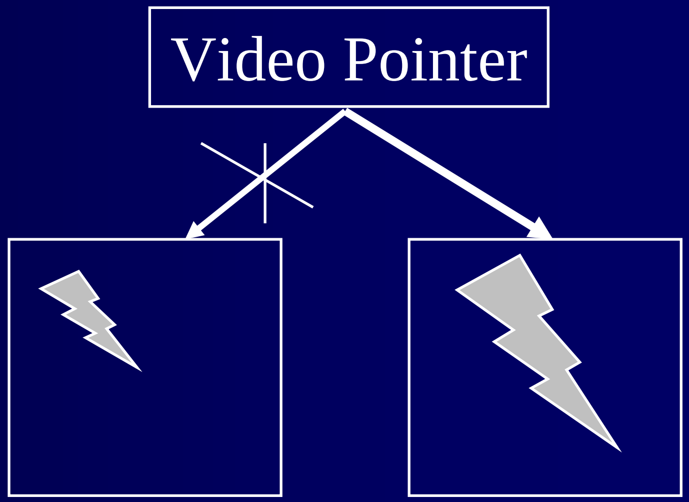
Putting it all together

$$\begin{vmatrix} sx*cos & -sx*sin & 0 \\ sy*sin & sy*cos & 0 \\ dx & dy & 1 \end{vmatrix}$$

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

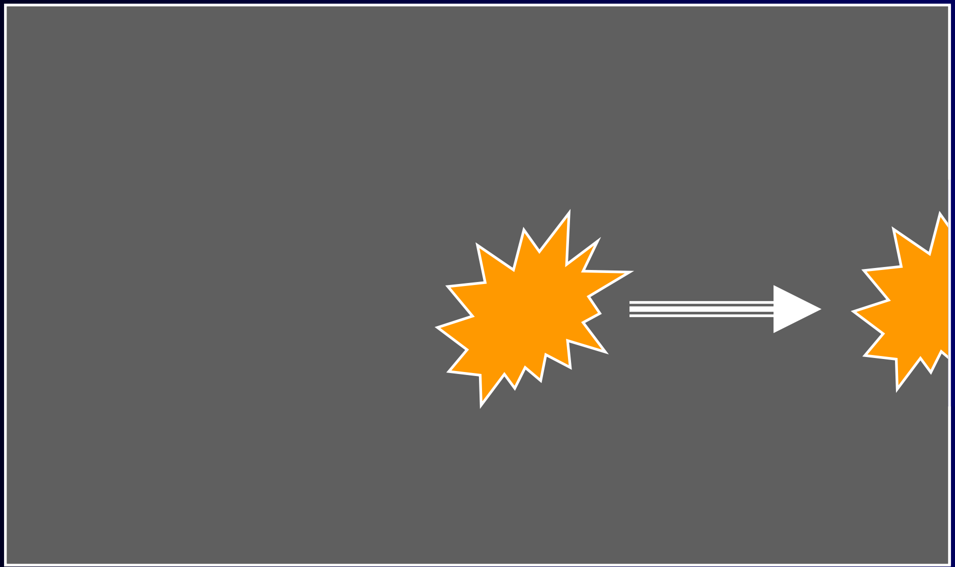
Image Space vs. Object Space

- 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

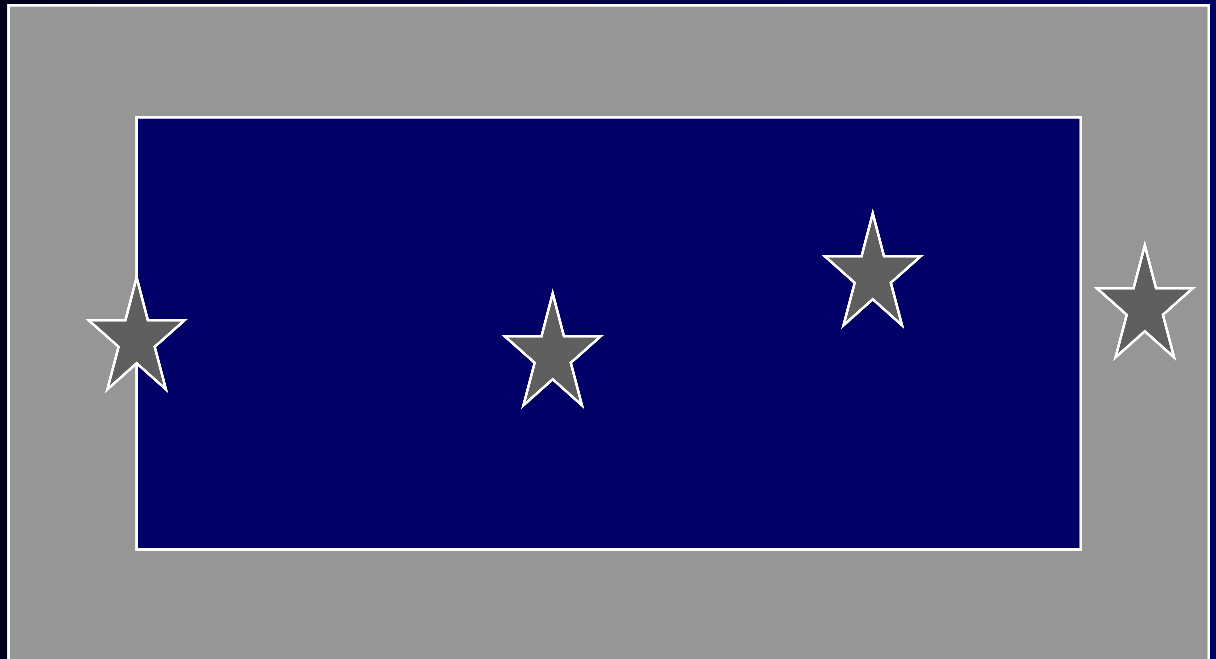
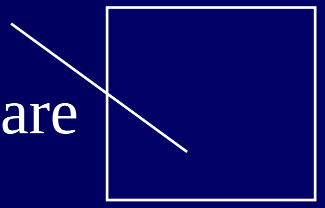


Image Space Clipping

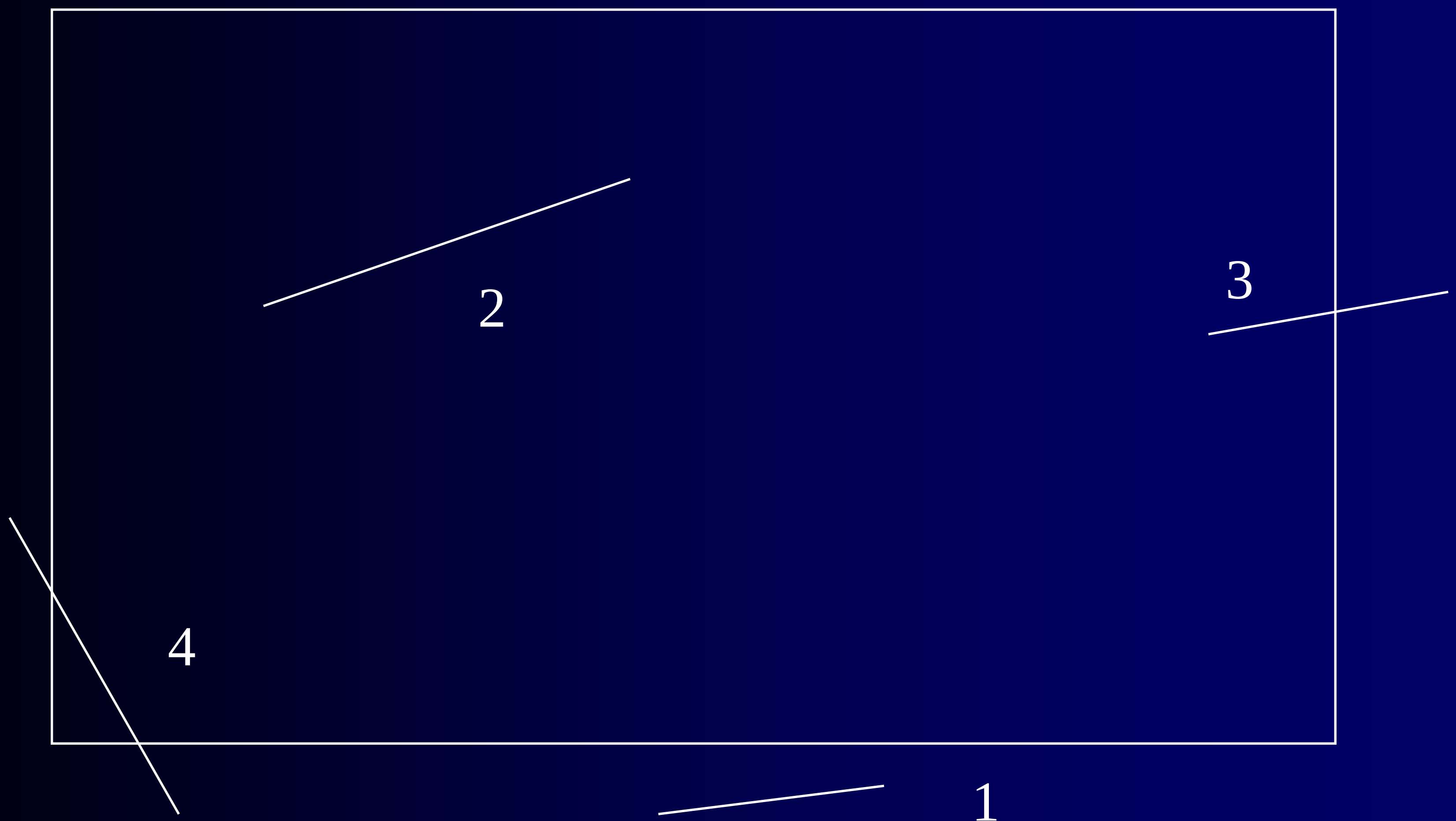
- Image Space:
  - The pixel-level representation of the complete image.
- Clipping
  - For each point, test if it is in the region that can be drawn before trying to draw it
  - If buffer is 320x200, test 0-319 in x, 0-199 in y.
- Evaluation
  - Easy to implement
  - Works for all objects: lines, pixels, 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

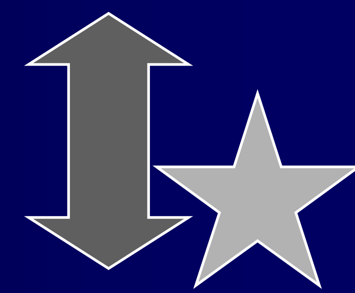


Line Clipping Cases

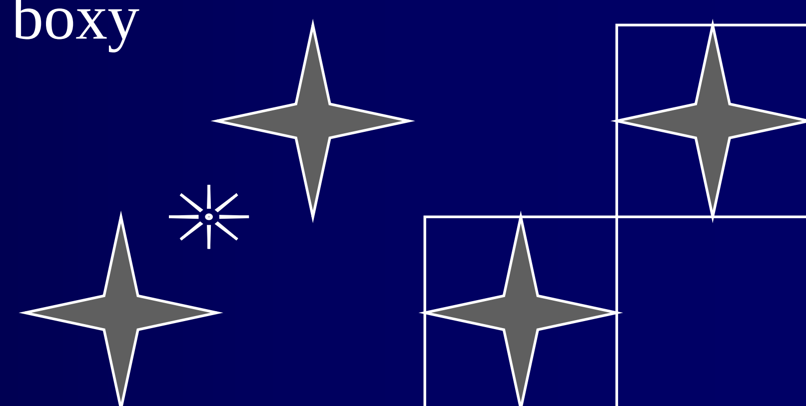


Collision Detection

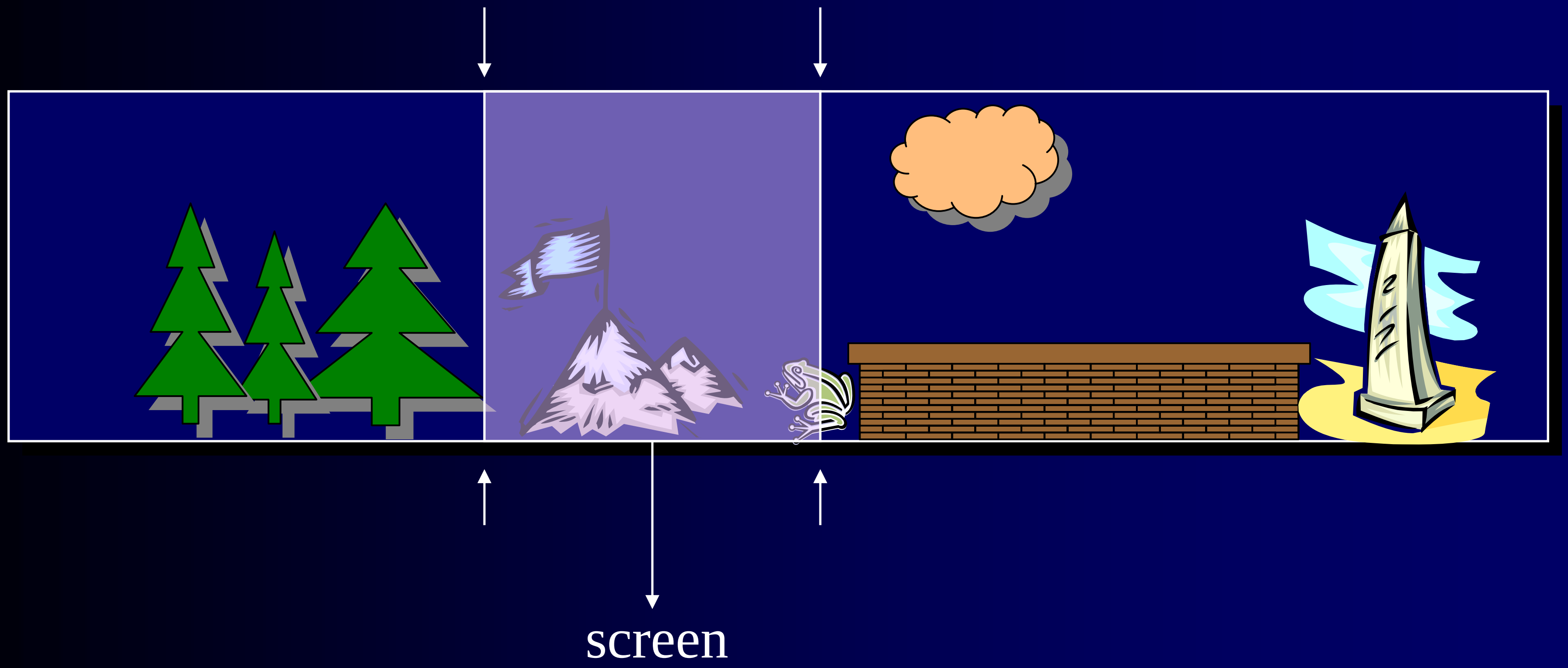
- Image Space:
  - Pixel by pixel basis. Expensive.
- Object Space:
  - Hard for complex and concave spaces:



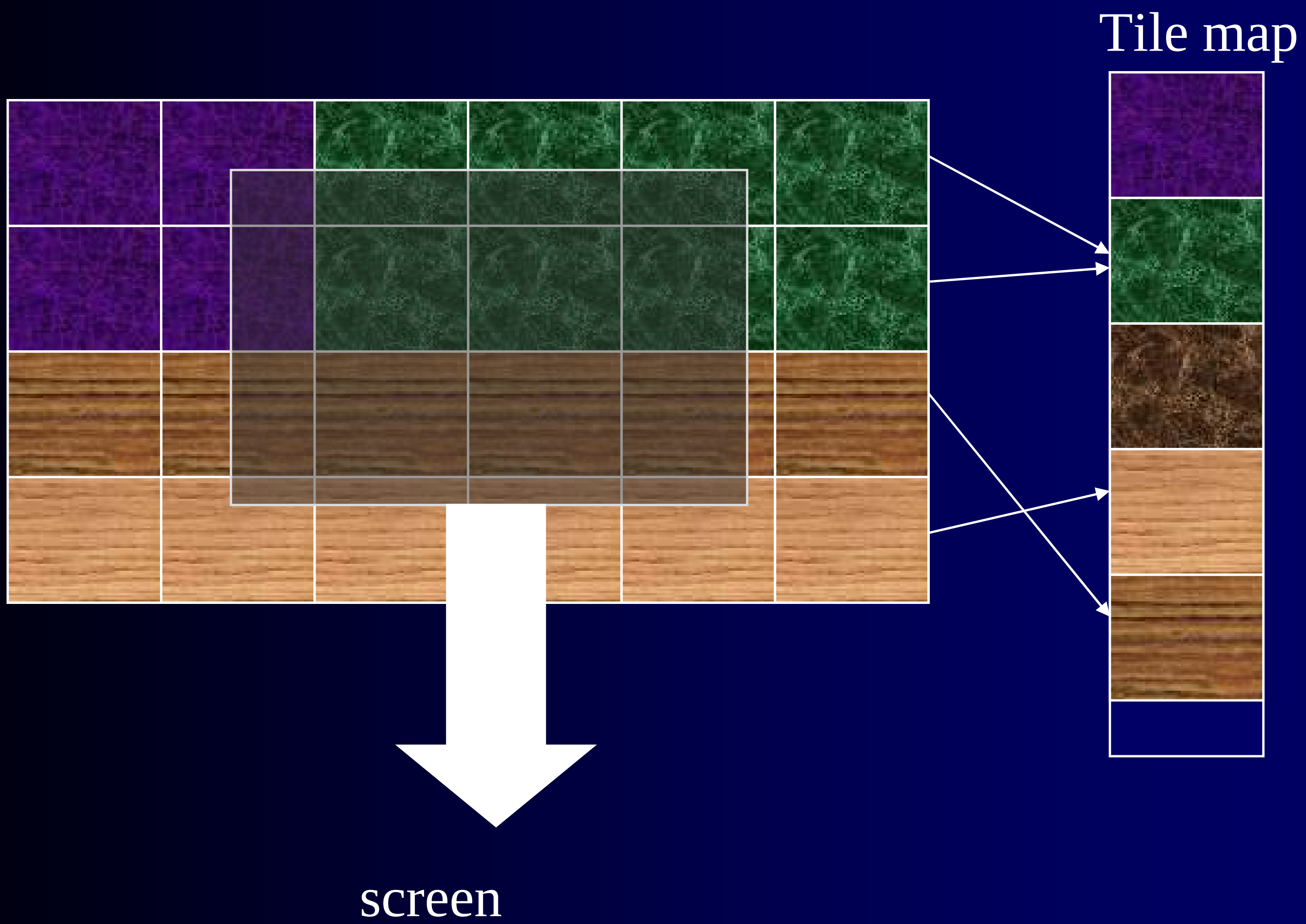
- Standard Approach:
  - Cheat!
  - Create a bounding box or circle
    - test each vertex to see in another object
  - Hide this by making your objects boxy
  - Don’t have objects like:



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