Coordinate Systems

- Modeling/local coordinates
- World coordinates
- Normalized device coordinates
- Device coordinates

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Modeling/Local Coordinates

- Convenient for object to be drawn
- Typical units: meters, feet, etc.
- Might not be Cartesian
- floats and doubles are common

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World Coordinates

- Groups of objects are combined
- Form a complete image
- Allows prototype objects
  - Drawn in local coordinates
  - Copied, resized and moved into world coordinates
- Units still feet, meters, etc.

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Normalized Device Coordinates

- Device-independent
- Horizontal and vertical ranges of 0 to 1
- "Independence" layer between world and various devices
  - Screen (windows of various sizes)
  - Printer

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Device Coordinates

- Actual pixels to draw
- Allows for movable drawing windows
  - Usually handled by the O/S
- Pixel size (pixels/inch) is relevant
- Typical processing
  - $(x_{mc},y_{mc}) \rightarrow (x_{wc},y_{wc}) \rightarrow (x_{ndc},y_{ndc}) \rightarrow (x_{dc},y_{dc})$

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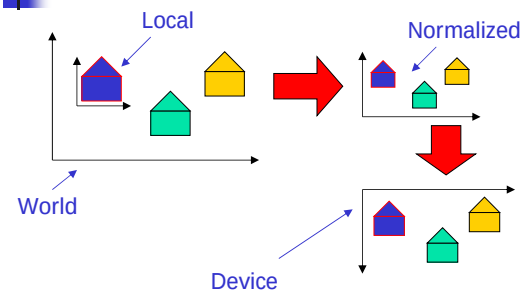
Coordinate System Example



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Drawing with Pixels

- Drawing algorithms
  - Point, line, circle, etc.
  - Assume pixels centers as reference
- Real pixels have finite size
  - Affects graphic primitive rendering
- Inter-pixel distances are fixed
  - Limited precision

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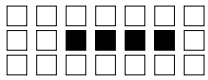
Pixel Addressing

- Addressing a pixel by its center leads to problems
- A pixel occupies a finite space
  - It is not a true “point”
- Consider a line from (2,1) to (5,1)
  - Actual length = 3
  - Drawn length = 4



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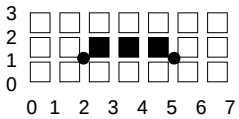
Boundary Addressing (1)

- Address pixels by their “boundaries”



- This “removes” the last pixel
  - Still not ideal

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Compensating for Pixel Size

- Ignore the problem?
  - May make little difference
  - Lines may be connected anyway
- Shrink object by one pixel?
  - Sometimes done when filling
    - E.g., filling rectangle drops a pixel row, column

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Boundary Addressing (2)

- We attempt to plot the interior of objects
  - Usually plot point if center is inside boundary
    - Compare with midpoint circle
  - Works better for squares etc.
  - Circles (text, p. 122)
- Still not ideal
  - Point are not infinitesimally small
  - Lines have finite width
  - Inside / outside / somewhere between?

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Filling

- We can draw outlines
  - Polygons
  - Circles and other conics
- How do we make them solid?
  - Scan lines
    - A carefully drawn outline has pixels on each scan line

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Basic Approach

- For each scan line
  1. Determine the intersection with all boundaries
     - Look for active outline pixels –or–
     - Find them mathematically
  2. Sort the intersection points
  3. Scan line from left to right
  4. Start outside
  5. At each intersection, toggle in/outness

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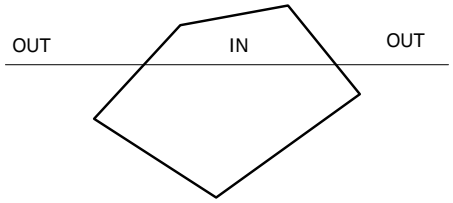
Example 1



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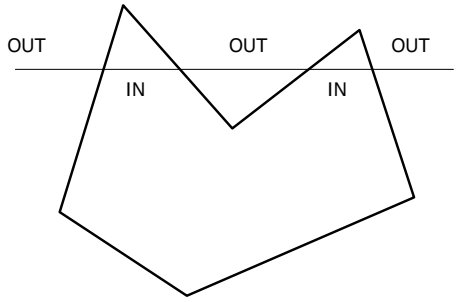
Example 2



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