CLIPPING ON A RASTER DISPLAY

- Clipping:
  - Remove points outside a region of interest.
  - Discard (parts of) primitives outside of window.
- Point clipping:
  - Remove points outside window.
  - A point is either entirely inside the region or not.
- Line clipping:
  - Remove portion of line segment outside window.
- Polygon clipping:
  - Remove portion of polygon outside window.

Approaches to Clipping

- Analytically:
  - best for floating-point packages
  - scan convert the clipped primitives
- During scan conversion as part of span arithmetic-scissoring:
  - good for filled or thick primitives
  - only extrema need be clipped
  - good if primitives not much larger then clip rectangle
  - not too many extra pixels generated
- As part of copy-pixel operation:
  - useful when likely to have window pan over large canvas

Role of Analytical Clipping

- Floating-point packages:
  - clip then scan convert
- Integer packages:
  - pre-clip and scan convert or
  - clip during scan conversion
- Common strategy:
  - clip lines and polygons analytically
  - clip other primitives during scan conversion

Analytic Clipping of Lines against Rectangles

- Lines are always clipped to at most one line segment
- Lines on rectangle border consider inside (displayed)

Clipping Rules

- Consider only end-points
- If both inside rectangle - trivially accepted
- One inside, one outside - need to compute intersection
- Both outside - may or may not intersect with clip rectangle

Computing Intersections

- Brute force:
  - intersect each line with 4 edges of clip rectangle
  - need to solve for intersection point per edge
  - treat line and edge as infinite
  - solve for intersection
  - test if intersection is interior to line and edge
  - each intersection involves solving 2 simultaneous equations and the interior test
Computing Intersections

- Could use slope-intercept formula
  - really for infinite lines - does not handle vertical
- Use parametric form instead
  - \( x = x_0 + t(x_1 - x_0), \ y = y_0 + t(y_1 - y_0), \ t \in [0,1] \)
  - solve for \( t_{\text{edge}} \) and \( t_{\text{line}} \)
  - if both lie in \([0,1]\) then real intersection
  - still need to test for lines parallel to clip rectangle edges
  - Still involves much calculation

Cohen-Sutherland Algorithm

- Performs tests to avoid calculations
  - check for trivial acceptance
  - do region tests e.g. if both endpoints lie to left of rectangle trivially rejected etc.
  - if neither divide line segment in two at clip edge
    - trivially reject one
  - continue comparing against each clip edge
- Efficient if clip rectangle large (almost all inside) or small (almost all outside) picking window

Outcodes

- Divide plane of clip rectangle into 9 regions
- Assign 4 bit code to each - each bit (1 or 0) indicates position wrt outside half-plane of clip edge
- Can calculate efficiently as sign bit of \((y_{\text{max}} - y)(y - y_{\text{min}}), \ (x_{\text{max}} - x)(x - x_{\text{min}})\)

Cohen-Sutherland Procedures

- Consider endpoints of line segment
  - Both outcodes 0000, line inside, trivially accept
  - Both in outside plane of same edge, trivially reject
  - if logical AND of outcode not 0 trivially reject
  - If neither, subdivide at edge
    - throw away outside segment
  - Convention: go top to bottom, right to left i.e. follow the bit order in the outcode
  - Outcode property: if bit set, line crosses edge
    - makes it easy to divide segment at edge

Efficiency

- use bitwise arithmetic for outcodes
- do not recalculate slopes
- Not most efficient
  - sometimes needless clipping e.g. clip line at clip line outside clip rectangle
  - Nicholl, Lee, Nicholl avoids this
- Advantage of Cohen-Sutherland
  - extension to 3D orthographic view volume straightforward
Clipping Polygons against Rectangles
- Clipping rectangle gives (at most) rectangle
- Clipping convex polygon gives convex polygon
- Clipping concave polygon may produce more than one concave polygon
- Clipping a circle or ellipse may result in up to 4 arcs

Sutherland-Hodgman Algorithm
- Clip polygon (convex or concave) against any convex clipping polygon
- 3D: against convex polyhedral volumes defined by planes
- Accepts a set of vertices
- Clips against a single infinite clip edge and outputs another series of vertices
- Clips against next plane etc.
- At each step 0, 1 or 2 vertices are added to output list
- To test if point is inside, test sign of dot product of normal to clip boundary and the polygon edge
- For upright clip rectangle, sign of distance to boundary

Improvements and Generalizations
- Can structure so that it is reentrant
- so no intermediate storage is required
- Pass polygon through pipeline of clippers
- makes suitable for hardware implementation