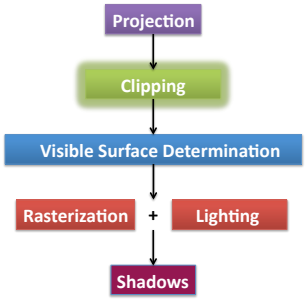
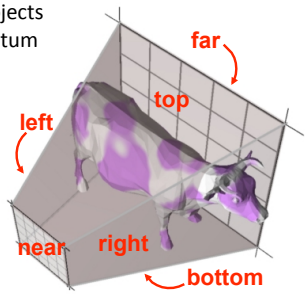
Clipping

Rasterization Pipeline Reminder



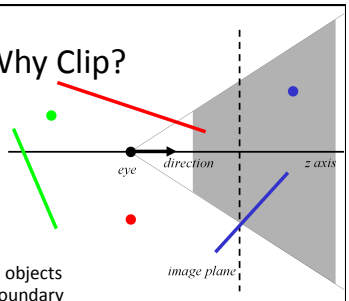
Clipping

- Eliminate portions of objects outside the viewing frustum
- View Frustum
  - boundaries of the image plane projected in 3D
  - a near & far clipping plane
- User may define additional clipping planes



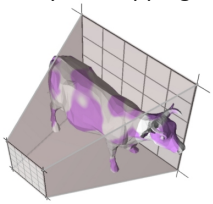
Why Clip?

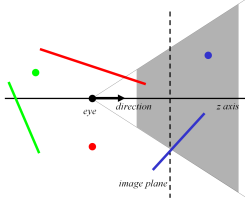
- Avoid degeneracies
  - Don't draw stuff behind the eye
  - Avoid division by 0 and overflow
- Efficiency
  - Don't waste time on objects outside the image boundary
- Other graphics applications (often non-convex)
  - Hidden-surface removal, Shadows, Picking, Binning, CSG (Boolean) operations (2D & 3D)



Clipping Strategies

- Don't clip (and hope for the best)
- Clip on-the-fly during rasterization
- Analytical clipping: alter input geometry



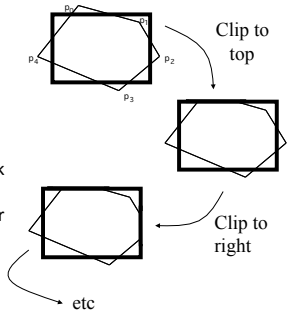


Clipping Summary

- It's the process of finding the exact part of a polygon lying inside the view volume
- To maintain consistency, clipping of a polygon should result in a polygon, not a sequence of partially unconnected lines
- We will first look at 2 different 2D solutions and then extend one to 3D

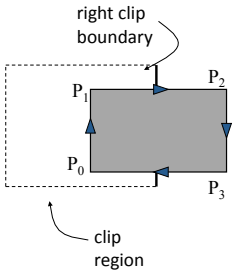
Sutherland-Hodgman Algorithm

- Clip the polygon against each boundary of the clip region successively
- Result is possibly NULL if polygon is outside
- Can be generalised to work for any polygonal clip region, not just rectangular



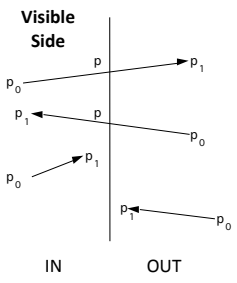
Clipping To A Region

- To find the new polygon
  - iterate through each of the polygon edges and construct a new sequence of points
  - starting with an empty sequence
  - for each edge there are 4 possible cases to consider



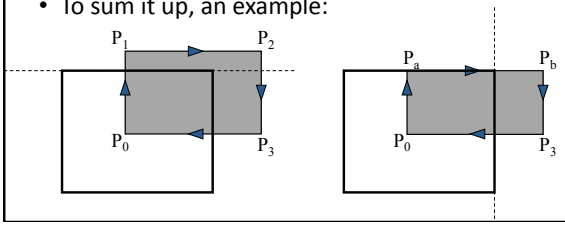
Clipping a polygon edge against the boundary

- Given an edge P0,P1 we have 4 case. It can be:
  - entering the clip region, add P and P1
  - leaving the region, add only P
  - entirely outside, do nothing
  - entirely inside, add only P1
- Where P is the point of intersection



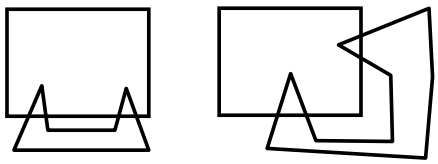
Still the Sutherland-Hodgman

- We can determine which of the 4 cases and also the point of intersection with just if statements
- To sum it up, an example:



Problems with Sutherland-Hodgman

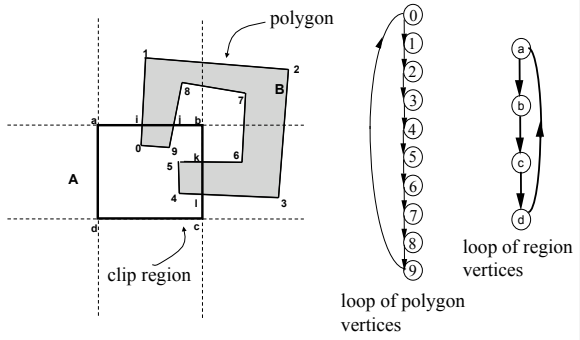
- What if you clip these?



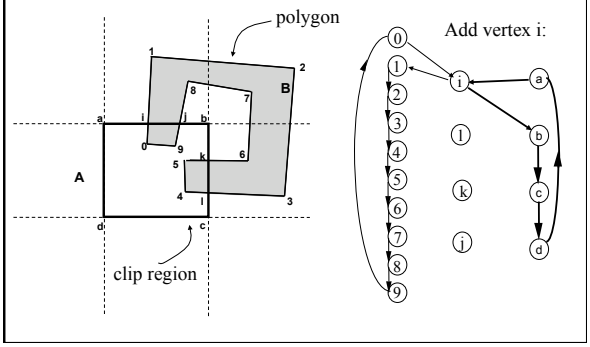
Weiler-Atherton Algorithm

- When we have non-convex polygons then the algorithm above might produce polygons with coincident edges
- This is sometimes OK for rendering but is not for other applications (e.g. shadows)
- The Weiler-Atherton algorithm produces separate polygons for each visible fragment

Weiler-Atherton Algorithm



Find the intersection vertices and connect them in the two lists



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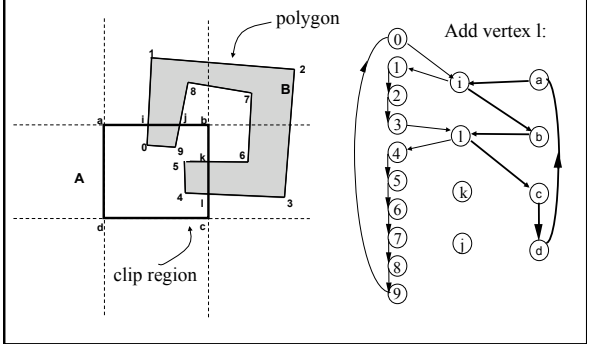

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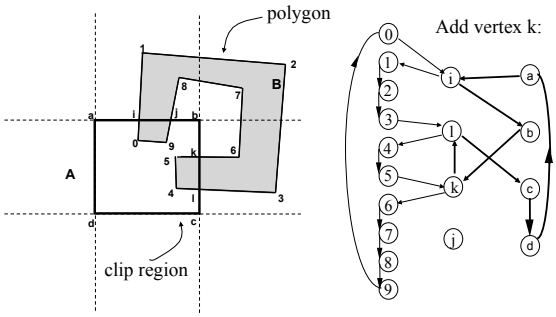
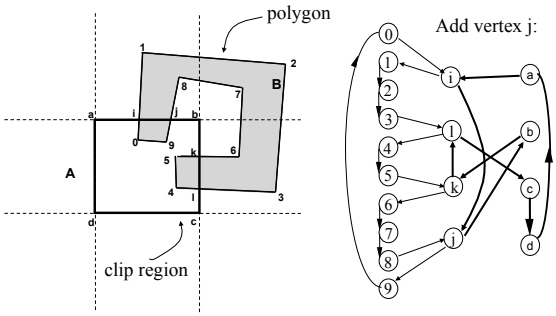
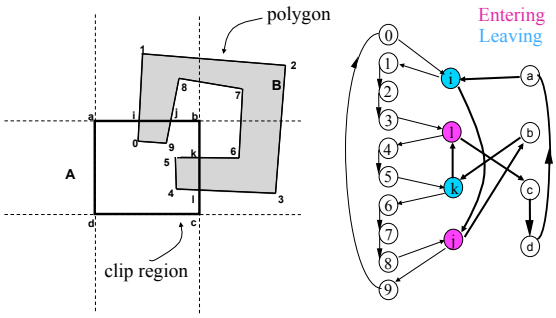


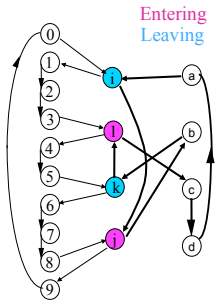
Completed Loop



Classify each intersection vertex as Entering or Leaving

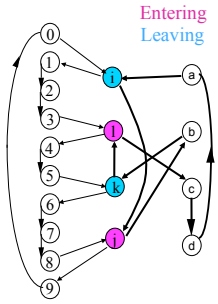


Capture clipped polygons



- Start at an entering vertex
- If you encounter a leaving vertex swap to right hand (clip polygon) loop
- If you encounter an entering vertex swap to left hand (polygon) loop
- A loop is finished when you arrive back at start
- Repeat whilst there are entering vertices

Capture clipped polygons



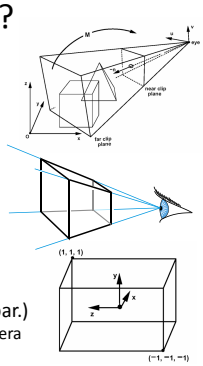
- Loop 1:
  - L, 4, 5, K
- Loop 2:
  - J, 9, 0, I

Clipping Polygons in 3D

- The Sutherland-Hodgman can easily be extended to 3D
  - the clipping boundaries are 6 planes instead of 4 lines
  - intersection calculation is done by comparing an edge to a plane instead of edge to edge

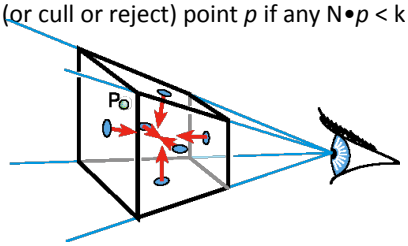
When to clip?

- Before perspective transform in 3D space
  - Use the equation of 6 planes
  - Natural, not too degenerate
- In homogeneous coordinates after perspective transform (Clip space)
  - **Before** perspective divide (4D space, weird *w* values)
  - Canonical,independent of camera
  - The simplest to implement in fact
- In the transformed 3D screen space after perspective division (canonical par.)
  - Problem: objects in the plane of the camera



Clipping with respect to View Frustum

- Test against each of the 6 planes
  - Normals oriented towards the interior
- Clip (or cull or reject) point *p* if any N•*p* < k



Clipping in Homogeneous Coord.

- The Sutherland-Hodgman can also be used for clipping in **4D before dividing** the points by the *w* coordinate
- This can have the advantage that is even more general, it even allows for the front clip plane to be behind the COP

Clipping in Canonical Parallel Space

- The view volume is defined by: $-1 \le x \le 1$, $-1 \le y \le 1$, $0 \le z \le 1$
- Testing for the 4 cases is fast, for example for the x = 1 (right) clip plane:
  - x0 ≤ 1 and x1 ≤ 1 entirely inside
  - x0 ≤ 1 and x1 > 1 leaving
  - x0 > 1 and x1 ≤ 1 entering
  - x0 > 1 and x1 > 1 entirely outside

In Reality

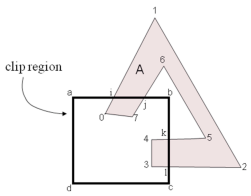
- GPUs used to implement 4D clipping
- Nowadays they seem to do 2D homogenous clipping…

Clipping Recap

- Sutherland-Hodgman is simple to describe but fails in certain cases
- Weiler-Atherton clipping is more robust but more complex
- Both extend to 3D but we need to consider projection and end up clipping in 4D

Exercise

- The following shape (A) is to be clipped against a rectangular clipping area. Apply the Weiler-Atherton clipping method and determine the clipped shape.



- The vertices of the clipping area are labelled a, b, c, d. The vertices of the shape are numbered from 0 to 7. The intersections of the shape's edges and the clipping rectangle are labelled i, j, k, l.