Normal Estimation and Clipping Methods
Normal Vectors

• How to compute the normal per planar face?

\[ n(T) = \frac{(x_j - x_i) \times (x_k - x_i)}{||(x_j - x_i) \times (x_k - x_i)||} \]
Normal Vectors

• However, vertex normals are not well defined

• Nevertheless, assume the shape is smooth

\[ n(v) = \frac{\sum_{T \in N_1(v)} \omega_T n(T)}{\left\| \sum_{T \in N_1(v)} \omega_T n(T) \right\|} \]

• How to choose \( \omega_T \)? E.g., \( \omega_T = 1, |T|, \theta_T \)
Normal Vectors

• How to **transform** normal vectors?

• Using the transformation matrix won’t work!
Normal Vectors

• How to transform normal vectors?

• The following should hold

\[ n \cdot t = 0 = (Gn) \cdot (Mt) \]

• Thus, \( G^T M = I \) \( \Rightarrow \) \( G = (M^{-1})^T \)
Clipping

• When and how to perform clipping?

• **Wireframe** rendering:
  – Clipping can be done in screen coordinates
  – Cull/Draw the triangle if it is outside/inside
  – Border triangles:
    • Line-Segment clipping or
    • Ignore pixels
Line-Segment Clipping

• Given two endpoints \((x_1, y_1)^T\) and \((x_2, y_2)^T\)

• Line segment in parametric form: \(\alpha \in [0,1]\)

\[
x(\alpha) = (1 - \alpha)x_1 + \alpha x_2,
\]
\[
y(\alpha) = (1 - \alpha)y_1 + \alpha y_2.
\]
Line-Segment Clipping

- Liang–Barsky [TOG ’84] Clipping

- Defer computation of line intersection as much as possible

\[ x(\alpha) = (1 - \alpha)x_1 + \alpha x_2, \]
\[ y(\alpha) = (1 - \alpha)y_1 + \alpha y_2. \]
Liang–Barsky Clipping

• A point is in the clip window if

\[ \begin{align*}
  x_{\text{min}} &\leq x_1 + \alpha \Delta x \leq x_{\text{max}}, \\
  y_{\text{min}} &\leq y_1 + \alpha \Delta y \leq y_{\text{max}}.
\end{align*} \]

\[
  x(\alpha) = x_1 + \alpha(x_2 - x_1), \\
  y(\alpha) = y_1 + \alpha(y_2 - y_1).
\]
Liang–Barsky Clipping

• A point is in the clip window if

$$\alpha p_k \leq q_k, \ k = 1,2,3,4$$

• Where

$$p_1 = -\Delta x, \quad q_1 = x_1 - x_{\text{min}}$$
$$p_2 = \Delta x, \quad q_2 = x_{\text{max}} - x_1$$
$$p_3 = -\Delta y, \quad q_3 = y_1 - y_{\text{min}}$$
$$p_4 = \Delta y, \quad q_4 = y_{\text{max}} - y_1$$
Liang–Barsky Clipping

• Determine the final line segment

  – Find $k$ for which $p_k < 0$, then $\alpha_1 = \max \left\{ 0, \frac{q_k}{p_k} \right\}$.

  – Find $k$ for which $p_k > 0$, then $\alpha_2 = \min \left\{ 1, \frac{q_k}{p_k} \right\}$.

  – Similarly for $\alpha_3$ and $\alpha_4$
Polygon Clipping

- Follows directly from line-clipping
- Apply clipping to the edges of the polygon
- Clipping a convex polygon against a convex polygon results in at most one convex object
Polygon Clipping

• We can implement a clipping pipeline

• Each clipper clips against one window’s edge
Polygon Clipping

• Example of **pipeline clipping**
Clipping

• When and how to perform clipping?

• Scan Conversion
  – Perform clipping before perspective division
  – The visible volume

\[
\begin{align*}
w & \geq x \geq -w, \\
w & \geq y \geq -w, \\
w & \geq z \geq -w.
\end{align*}
\]
Clipping

• For each model
  – Determine if it is inside/outside the view volume
    • Intersect its bounding box with the view volume

  – For each boundary model
    • Perform polygon-clipping for each triangle

• Thus, extend our clipping to three dimensions
Bounding Box

• How to compute the bounding box?

• Find the minimal/maximal coordinates
3D Polygon Clipping

• Extend Liang–Barsky with the equation

\[ z(\alpha) = (1 - \alpha)z_1 + \alpha z_2 \]

• Add near and far clippers in the pipeline

• Need to adjust intersection computations...
3D Polygon Clipping

- Plane–Line intersection is given by

\[
\alpha = \frac{n \cdot (p_0 - p_1)}{n \cdot (p_2 - p_1)}
\]
Suggested Readings

• Transforming Normals:

• Interactive Computer Graphics, Chapter 6

• Liang–Barsky Clipping: