IMGD 1001:
3D Art

Outline

- The Pipeline
- Concept Art
- 2D Art
  - Animation, Tiles
- 3D Art (next)
  - Modeling, Texturing, Lighting, Transformations

Polygonal Modeling Basics: Primitives

- *Primitives* are basic shapes
- Most 3d packages have same primitives:
  - Sphere, Cube, Cylinder, Plane
  - Use for "broad strokes"
- Concentrate on primitives within object
  - Ex: human body (ovals for shoulders, cylinders for legs, sphere for head…)
- *Components* are parts that make up primitive
  - Ex: vertices, edges, triangles, faces, elements
  - Similar across all packages but terminology can vary
- *Transformation* allows moving, rotating, scaling object or component

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Polygonal Modeling Basics: Normals

- Face normals are at right angle to polygon
  - Tell what direction if facing, how to render, how light will react
- Viewed from other side, is invisible
  - Fine if on inside (say, of solid cube)
- When debugging, pay attention to normals as well as polygons

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Polygonal Modeling Basics: Backface Culling

- Toggles display of faces that point away from view
  - When on, see through wireframe
  - When off, looks solid (not drawn)
- Makes look less cluttered

Modeling Tools

- Certain tools and techniques used 80-90% of the time
- *Line Tool*:
  - Draw outline of object and extrude to get 3-d shape
    - Ex: profile of car. Use line tool. Then, extrude outward to get shape.
- *Extrude*:
  - Take component (often face), duplicating it, pulling pushing or scaling to refine model
    - Ex: take cube. Extrude face outward and smaller
- *Cut*:
  - Subdivides faces and adds new faces
- *Adjust*:
  - The artistic part of modeling. Try to capture form, profile and character by moving vertices
    - "Vertex surgery", part of the technical manipulation

Based on Chapter 6.2, *Introduction to Game Development*

A Modeling Technique: Box Modeling

- Done for character, but can apply to other things
- General idea:
  - Start with box, cylinder or other primitive
  - Extrude, Cut, Adjust…
  - Get topology, proportions right
  - Once happy, refine until details complete

Box modeling: Quick Example

- Reference
- Box modeling: extrude, cut, adjust
- Compare to reference
- Shade

Based on Chapter 6.2, *Introduction to Game Development*

Polygons and Limits

- 3d Software renders scene of polygons like game
  - But 3d software slow (*Toy Story* 1 frame / 15 hrs)
  - Game is real time (30 frames / second)
- Need to limit polygons. How spent depends upon world size and where needed.
  - Ex: *Medal of Honor* versus *Soul Caliber 2*. MoH details spread across world, less on avatars. SC2 can have detailed avatars since only 2 in one ring.
- Think of *how many* polygons each item needs. Estimates, educated guesses. Then, make pass. (Tools will often give count)
  - Used wisely, can make detailed scenes with few (Ex: 2.5, page 24)
  - Ch 6.2 assumes 4000 (typical for PS2 street fighting game or hero in 3rd person action game)

Based on Chapter 2, *Creating the Art of the Game*, by Matthew Omernick

Polygon Reduction (1 of 4)

- Being able to model without wasting polygons important → takes practice
- If a player will see face?
  - Ex: oil barrel as cylinder. Will see bottom? Nope, then delete.
- Are all faces necessary? Looks great, yeah, but some can be removed.
  - Ex: 12-sided cylinder still looks "round" with 8 sides? Then do it.
- (Example exercise p30-31)

Based on Chapter 2, *Creating the Art of the Game*, by Matthew Omernick

Polygon Reduction (2 of 4)

- Level-of-detail (LOD) meshes
  - Multiple versions of object, progressively lower levels
- When far away, use low level
  - Assume more objects in Field of View
- When close, use higher level
  - Assume fewer objects in Field of View

Polygon Reduction (3 of 4)

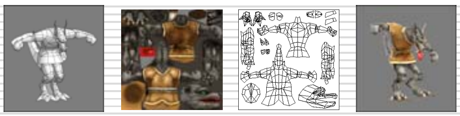
- For entire level (ie- map with environment), entire polygon count matters
  - Impacts amount of memory needed
- But only visible polygons rendered
  - Rest are "culled" and not computed

Images courtesy of WildTangent

Based on Chapter 6.2, *Introduction to Game Development*

Polygon Reduction (4 of 4)

- With low polygon modeling, much of the detail is painted into the texture (next topic!)



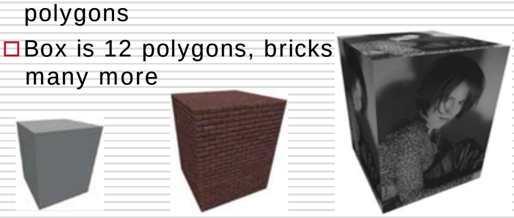
Images courtesy of WildTangent, model and texture by David Johnson.

Texture

- *Shader* – define surface property of object – how shiny, bumpy, how light effects
- *Texture* – bitmap plugged into shader that defines image we want to appear on object

Detail in Texture

- Add depth, lines, etc. without polygons
- Box is 12 polygons, bricks many more



(Taken from http://www.mostert.org/3d/3dpdzscenem.html)

Lighting

- Can conjure feelings, emotions, even change what you are seeing
  - Reveal (or hide) depth
  - (Many books on traditional lighting)
  - AR/ID 3150. LIGHT, VISION AND UNDERSTANDING
- Color, Mood

The Role of Color

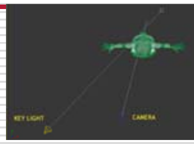
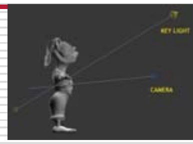
RTX Red Rock

Color indicates danger

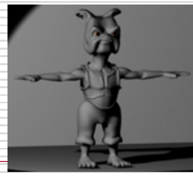
The Role of Lighting

Long shadows not only add to the atmosphere, but also help break up repetition

Lighting Setup (1 of 3)

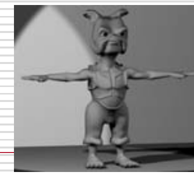



Key light – main source.
The Key light is placed next to the camera, about 35-45 degree angle to the subject. The angle is determined by what kind of mood that you want the scene to have.

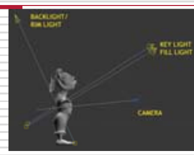


Lighting Setup (2 of 3)

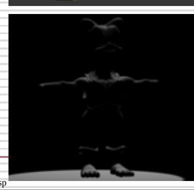

Fill light – Brings out some details out of shadow.
Place the Fill Light at a 90 degree angle from the Key Light, usually slightly higher or lower than the Key Light.



Lighting Setup (3 of 3)

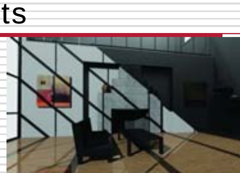
Backlight - Highlights edges, pulls away from background. Placed directly opposite the camera and behind the subject.



Working with 3D Lights

- *Directional Lights* – used for sunlight or moonlight. Often as key light. Predictable.
- *Spot Lights* – focus beam on single location. Great control.
- *Point Lights* – single point in all directions. Light bulbs, candles, etc.
- *Ambient Lights* – spread everywhere, equally. Uniform diffuse lights. Precise control over illumination.

Example of Working with 3D Lights




Ambient light

Effective Lighting Practices (1 of 2)

Pools of light
- Don't always try to light evenly.
- *Gives sense of mystery*

Pools of light in Indiana Jones: The Emperor's Tomb

Effective Lighting Practices (2 of 2)

Guide lights –
- Use light to guide the player.
- Helps highlight areas that are accessible and important to the objectives.

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Based on Chapter 6.6, *Introduction to Game Development*

Introduction to Transformations

- A *transformation* changes an object's
  - Size (scaling)
  - Position (translation)
  - Orientation (rotation)
- Transform object by applying sequence of matrix multiplications to object vertices

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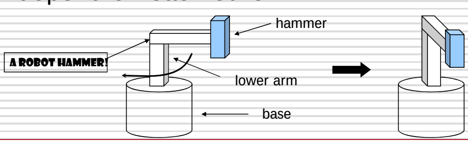
Hierarchical Transformations

- Graphical scenes have object dependencies
- Many small objects
- Attributes (position, orientation, *etc.*) depend on each other



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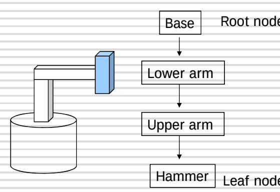
Hierarchical Transformations

- Object dependency description using tree structure



Object position and orientation can be affected by its parent, grand-parent, grand-grand-parent, ... nodes

Hierarchical representation is known as **Scene Graph**

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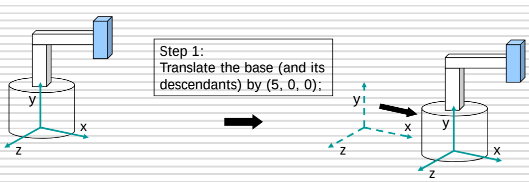
Hierarchical Transformations

- Relative Transformations - Specify the transformation for each object relative to its parent



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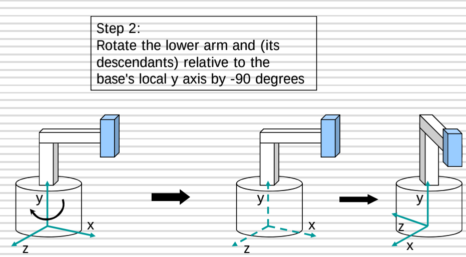
Hierarchical Transformations



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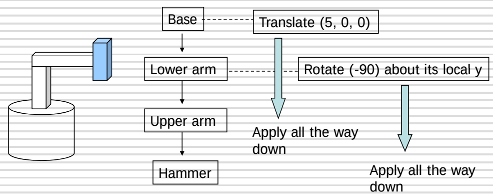
Hierarchical Transformations



Transformation uses Matrices

- All transformations can be performed using matrix/vector multiplication
- Allows pre-multiplication of all matrices
- Note: point (x, y) needs to be represented as (x, y, 1), also called ***homogeneous coordinates***

Point Representation

- We use a column matrix (2x1 matrix) to represent a 2D point

$$\begin{pmatrix} x \\ y \end{pmatrix}$$

- General form of transformation of a point *(x, y)* to *(x', y')* can be written as:

$$x' = ax + by + c$$
$$y' = dx + ey + f$$

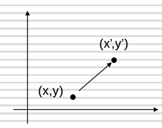
or

$$\begin{pmatrix} x' \\ y' \\ 1 \end{pmatrix} = \begin{pmatrix} a & b & c \\ d & e & f \\ 0 & 0 & 1 \end{pmatrix} * \begin{pmatrix} x \\ y \\ 1 \end{pmatrix}$$

Translation

- To reposition a point along a straight line
- Given point *(x, y)* and translation distance (t_x, t_y)
- The new point: *(x', y')*

$x' = x + t_x$
$y' = y + t_y$



or

$P' = P + T$ where $P' = \begin{pmatrix} x' \\ y' \end{pmatrix}$ $P = \begin{pmatrix} x \\ y \end{pmatrix}$ $T = \begin{pmatrix} t_x \\ t_y \end{pmatrix}$

3x3 2D Translation Matrix

$x' = x + t_x$
$y' = y + t_y$

$$\begin{pmatrix} x' \\ y' \end{pmatrix} = \begin{pmatrix} x \\ y \end{pmatrix} + \begin{pmatrix} t_x \\ t_y \end{pmatrix}$$

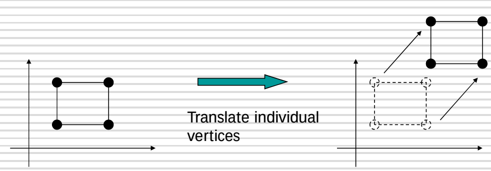
use 3x1 vector

$$\begin{pmatrix} x' \\ y' \\ 1 \end{pmatrix} = \begin{pmatrix} 1 & 0 & t_x \\ 0 & 1 & t_y \\ 0 & 0 & 1 \end{pmatrix} * \begin{pmatrix} x \\ y \\ 1 \end{pmatrix}$$

Note: it becomes a matrix-vector multiplication

Translation of Objects

- How to translate an object with multiple vertices?

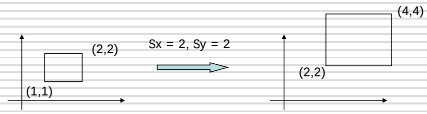


2D Scaling

- Scale: Alter object size by scaling factor (Sx, Sy). *i.e.*,

*x' = x * Sx*
*y' = y * Sy*

$$\begin{pmatrix} x' \\ y' \end{pmatrix} = \begin{pmatrix} Sx & 0 \\ 0 & Sy \end{pmatrix} \begin{pmatrix} x \\ y \end{pmatrix}$$



3x3 2D Scaling Matrix

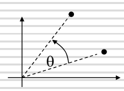
*x' = x * Sx*
*y' = y * Sy*

$$\begin{pmatrix} x' \\ y' \end{pmatrix} = \begin{pmatrix} Sx & 0 \\ 0 & Sy \end{pmatrix} \begin{pmatrix} x \\ y \end{pmatrix}$$

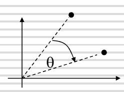
$$\begin{pmatrix} x' \\ y' \\ 1 \end{pmatrix} = \begin{pmatrix} Sx & 0 & 0 \\ 0 & Sy & 0 \\ 0 & 0 & 1 \end{pmatrix} * \begin{pmatrix} x \\ y \\ 1 \end{pmatrix}$$

2D Rotation

- Default rotation center is origin *(0,0)*



$\theta > 0$: Rotate counter clockwise

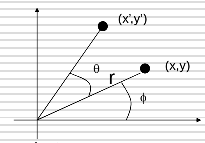


$\theta < 0$: Rotate clockwise

2D Rotation (cont.)

(x,y) → Rotate *about the origin* by θ

→ (x', y')



How to compute (x', y') ?

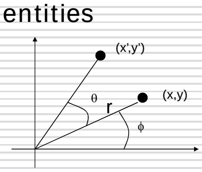
$x = r*\cos(\phi)$ $\quad x' = r*\cos(\phi + \theta)$
$y = r*\sin(\phi)$ $\quad y' = r*\sin(\phi + \theta)$

2D Rotation (cont.)

- Using trigonometric identities

$$\cos(\theta + \phi) = \cos\theta\cos\phi - \sin\theta\sin\phi$$
$$\sin(\theta + \phi) = \sin\theta\cos\phi + \cos\theta\sin\phi$$

$x' = x\cos(\theta) - y\sin(\theta)$
$y' = x\sin(\theta) + y\cos(\theta)$

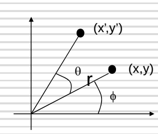


Matrix form?

$$\begin{pmatrix} x' \\ y' \end{pmatrix} = \begin{pmatrix} \cos(\theta) & -\sin(\theta) \\ \sin(\theta) & \cos(\theta) \end{pmatrix} \begin{pmatrix} x \\ y \end{pmatrix}$$

3x3 2D Rotation Matrix

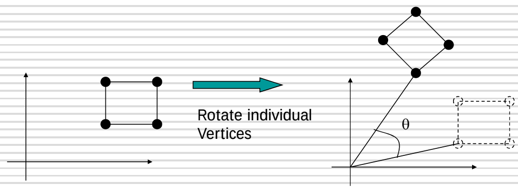
$$\begin{pmatrix} x' \\ y' \end{pmatrix} = \begin{pmatrix} \cos(\theta) & -\sin(\theta) \\ \sin(\theta) & \cos(\theta) \end{pmatrix} \begin{pmatrix} x \\ y \end{pmatrix}$$



$$\begin{pmatrix} x' \\ y' \\ 1 \end{pmatrix} = \begin{pmatrix} \cos(\theta) & -\sin(\theta) & 0 \\ \sin(\theta) & \cos(\theta) & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} x \\ y \\ 1 \end{pmatrix}$$

2D Rotation

- How to rotate an object with multiple vertices?



Arbitrary Rotation Center

- To rotate about arbitrary point P = (Px, Py) by θ:
  - Translate object by T(-Px, -Py) so that P coincides with origin
  - Rotate the object by R(θ)
  - Translate object back: T(Px, Py)
- In matrix form
  - T(Px,Py) R(θ) T(-Px,-Py) * P

$$\begin{pmatrix} x' \\ y' \\ 1 \end{pmatrix} = \begin{pmatrix} 1 & 0 & Px \\ 0 & 1 & Py \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} \cos(\theta) & -\sin(\theta) & 0 \\ \sin(\theta) & \cos(\theta) & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} 1 & 0 & -Px \\ 0 & 1 & -Py \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} x \\ y \\ 1 \end{pmatrix}$$

- Similar for arbitrary scaling anchor

Composing Transformations

- Composing transformations
  - Applying several transforms in succession to form one overall transformation
- Example
  - **M1 X M2 X M3 X P**

  where M1, M2, M3 are transform matrices applied to P
- Be careful with the order!
- For example
  - Translate by (5, 0), then rotate 60 degrees is NOT same as
  - Rotate by 60 degrees, then translate by (5, 0)