Hierarchical modeling

• Consider constructing a complex 2D drawing: e.g. an animation showing the plan view of a building, where the doors swing open and shut.

Floor
Corridor
Room
Body
Door
Adjoining walls

Options:
• Specify everything in world coordinate frame; but then each room is different, and each door moves differently.
• Exploit similarities by using repeated copies of models in different places (instancing).

Each arrow represents a transformation

Model form – scene graph
- Directed acyclic graph
- Each node consists of 0 or more objects (lines, polygons, etc.)
- Each edge is a transformation
- There can be many edges joining two nodes (e.g. in the case of the corridor - many copies of the same room model, each transformed differently).
- Every graphics API supports hierarchies - some directly (meaning you have to learn a language to express the model) some indirectly with a matrix stack.

Write the transformation from door coordinates to room coordinates as:

To render a body, use the transformation:

Matrix stacks and rendering

• Matrix stack:
  – Stack of matrices used for rendering
  – Applied in sequence.
  – Push=append a new matrix
  – Pop=remove last matrix
  – In previous example, body-device transformation comes from door-device transformation by popping door-room and pushing body-room.
Matrix stacks and rendering

- Root node has single edge with the world-to-device transformation.
- Algorithm for rendering a hierarchical model:
  - `render (root)`
- Recursive definition of `render (node)`
  - if node has object, render it
  - for each child:
    - push transformation
    - `render (child)`
    - pop transformation

Now to render door on first room in first corridor, stack looks like: W C1 R1 D1.
- For efficiency we would store “running” products, IE, the stack contains: W, W*C1, W*C1*R1, W*C1*R1*D1.
- We do not need two copies of corridor, or 16 copies of body; we render one copy using 16 different transformations. This is known as instancing.
- Animation requires care: if D1 is a single function of time, all doors will swing open and closed at the same time.

Stack is W
- render kneecap
- Stack is W L
- render ankle
- Stack is W L F
- render foot
- Stack is W L S
- render shin
- Stack is W T
- render thigh