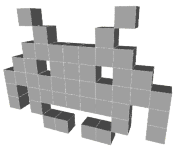
3D video games 2018/2019

the Scene Graph



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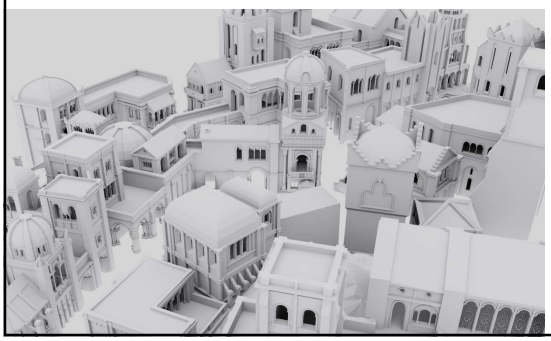


Recap: 3D Spatial Trasforms

- Math functions
  - input: point / vector / versor
  - output: point / vector / versor

  Thus, can be applied to e.g 3D models (apply it to evey vertex position and normal…)
- Typically:
  - Scaling + rotation + translation
- Modelling:
  - scaling up or down / size
    - isotropic (uniform) o anisotropic (deforming)
  - orientation in space / rotation
  - movement / position (traslation)

Recap: internal representations of 3D Spatial Trasforms

- Many possible ones, but typically:
  - translation (vec3) + scale (float or vec3)
    + rotation (3x3 matrix / quaternion / axis+angle / Euler angles)
- Regardless, we assume a transform is:
  - Light in memory (few tens of bytes)
  - Quick to apply (even to large, complex models)
    - It's done on-the-fly during rendering on the GPU
  - Quick to:
    - Interpolate with another (aka "blend" / "mix" / "lerp")
    - invert (find the opposite transform)
    - cumulate (find A*B) («they are closed w.r.t. = composition»)
- Always interpretable as a change of Reference frame
  - holds by def. for all the ones we care about: the "affine" ones

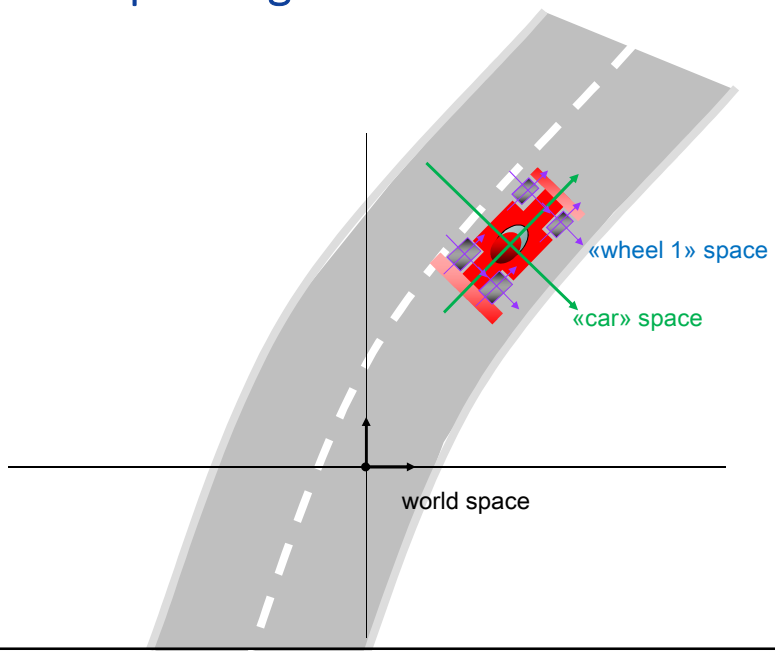
Recap: transformation associated to an object in the scene

- Any object associated to a spatial location in the game is given its transformation, which goes
- From:
  - local space *a.k.a.*
  - object space *a.k.a.*
  - pre-transform space
  - *a.k.a.* «castle» space / «hero» space / «camera» space / «chainsaw» space / «bazooka» space etc
- To:
  - global space *a.k.a.*
  - world space *a.k.a.*
  - post-transform space

Composite scenes: hierarchical transformations

- So far, we assumed that the transform of each object goes from local to global in one step
- In reality, scene is constructed hierarchically
- Objects are made of sub-objects
  - a city is made of houses made of walls made of bricks
  - a «hat» sits on an «head» which sits on a «character» which sits in a «spaceship» moving across the «scene»
- Also: different instances of one object can appear in multiple locations of the scene

Compositing scenes

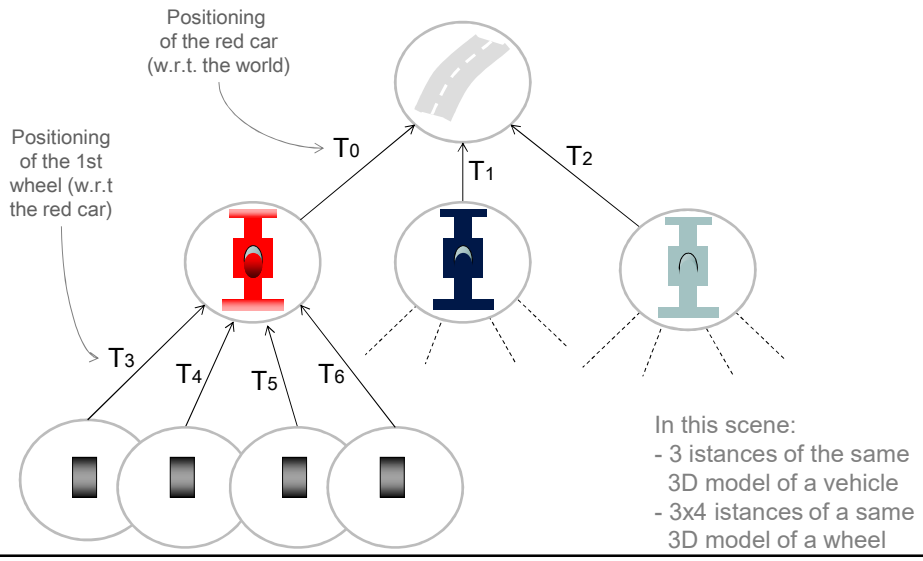


Scene graph

A tree (i.e. hierarchical structrure)

- Each nodes: a space (a reference frame)
- To each node we associate:
  - Instances to stuff…
    (3D models, lights, cameras, virtual microphones
    spawn points, explosions etc…)
- Root node: world space
- On the arches:
  - the local trasforms

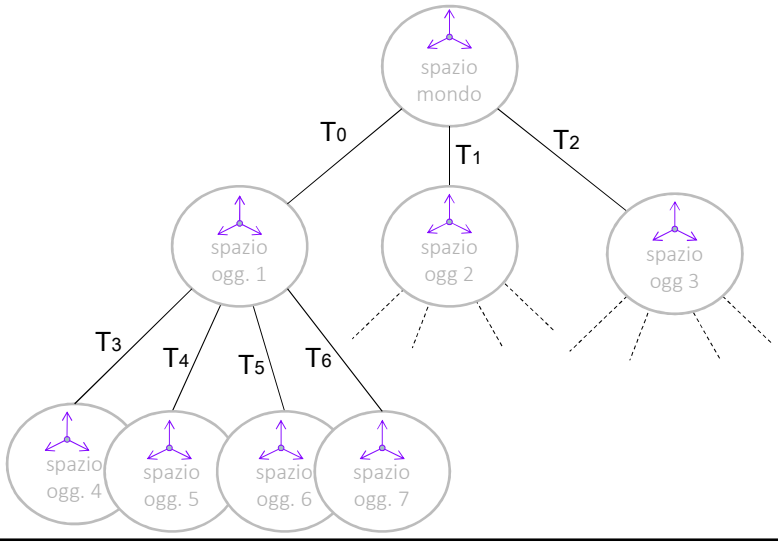
Scene graph



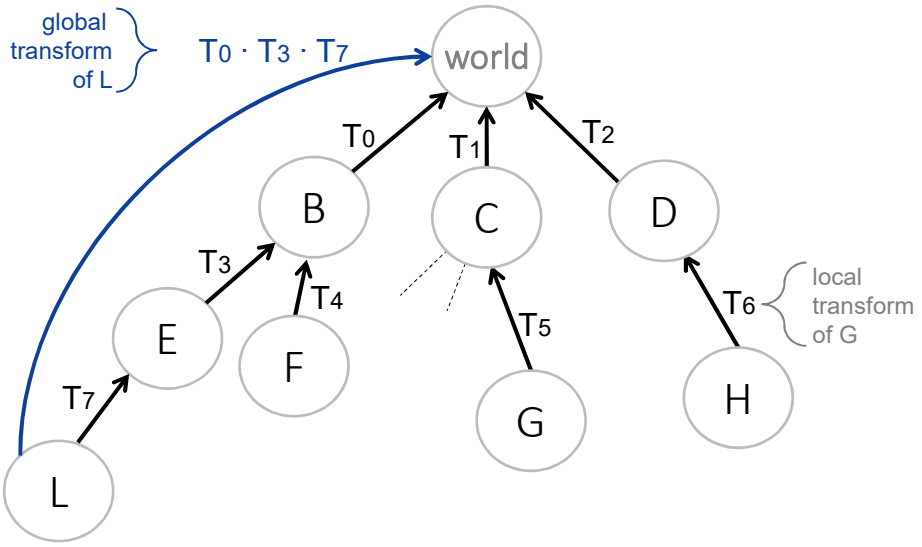
Local VS global Transform

- Local transform (a.k.a. «relative» tranform)
  - from a node space to its parent space
- Global transform (a.k.a. «absolute» transform)
  - from a node space to world space
  - obtained by: *cumulating* local transforms!
- benefit: changing the transforms of a node affects the entire subtree!

Scene graph



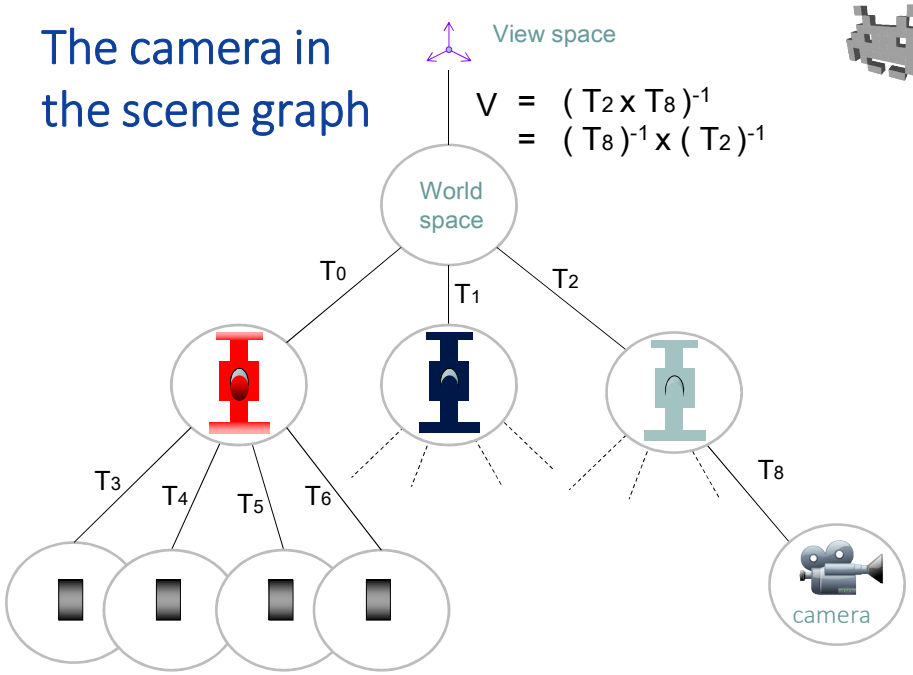
Example



The camera in the scene graph

- Camera:
  - just another element sitting somewhere the scene-graph
  - for the scene to be rendered, there must be a camera somewhere in the graph!
- the «camera space» (object-space of the camera obj) is special
  - aka View Space (Screen Space is similar)
  - in CG, the View Transformation V
    = inverse of Global Transform of camera node
    = from World-space to View-space
  - V is used in the rendering to determine where objects end up on the screen.
- Camera animations = move camera = change V
  - e.g. by script

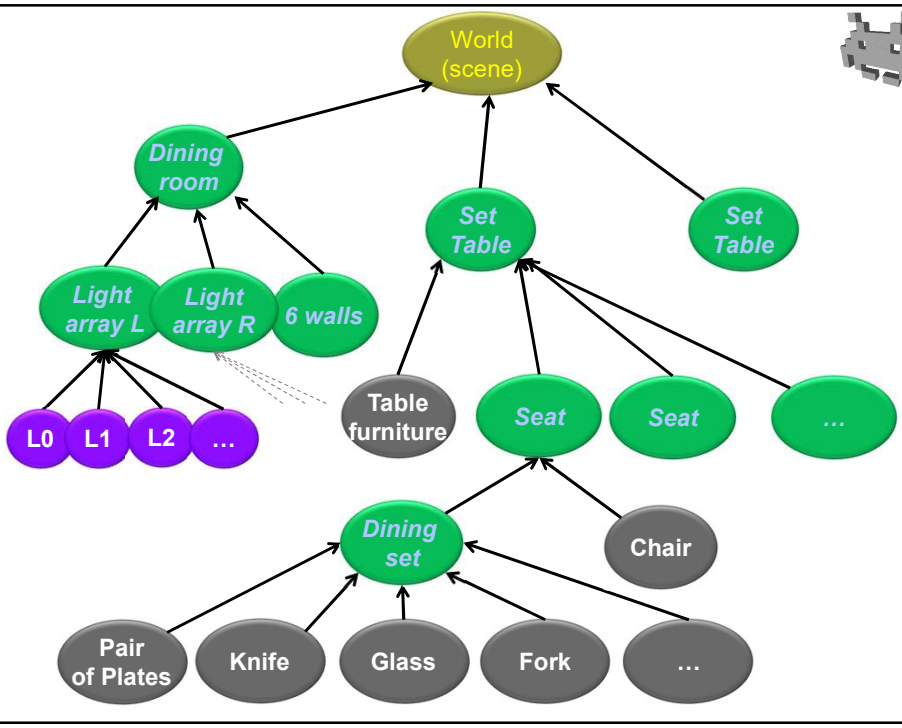
The camera in the scene graph



Scene Graph as a data structure

- Each engine / library adopts its own solution
- No standards
  - but file formats exits which can include a scene graph: e.g. COLLADA
- Typical concepts:
  - the Node class
    keeps the (local) transform to the father node
    (and / or childs, sibilings…)
  - also, links (eg. pointers) to instances / assets
  - global transforms are computed on demand
  - camera node is a special node
  - some mechanism is needed for repeated sub-trees

Example: a dining table



Example: a dining table

Nodes of a scene-graph in unity
GameObjects & Transforms

A node = a GameObject with

- a transform field, containing
  - its local transform
  - links to Parent, Children (and siblings) – which are transforms
- any number of associated "components", which represent anything residing in that node, like
  - Meshes (to display at this nodes)
  - Cameras: active one(s) produces the rendering(s)
  - "RigidBodies": objects controlled by the physics
  - "Colliders": geom proxies used for collisions
  - "Particle systems" : (i.e. the "emitters" of particles)
  - Sound producers / receivers
  - Scripts …
  - basically any asset!

Nodes of a scene-graph in unity
GameObjects & Transforms

- The Transformation actually stores the local transf:
  - **`localPosition`**, **`localRotation`**, **`localScale`**
  - remember: goes from this node to father node
- the Global transformation can be accessed via the properties:
  - **`position`**, **`rotation`**, **`scale`** ("global" is left implicit)
  - what does getting / setting them really do? exercise!
  - it doesn't work for "scale"! why? (because anisotropy)

feels like assigning / reading a field, actually means invoking setters/getters (C# trick)

Digression on unity :
properties and components

- Properties (C# mechanism)
  it feels like a field (you can read or assign it)
  but it's actually a getter and setter method
  - `obj.x = 3` *...means...* `obj.set_x( 3 )`
  - `foo = obj.x` *...means...* `foo = obj.get_x()`
- Components (Unity library mechanism)
  - A generic something attached to a GameObject
  - `GameObject g;`
    `g.getComponent< type >()`
    returns component of required type (if it exists)

base class for everything

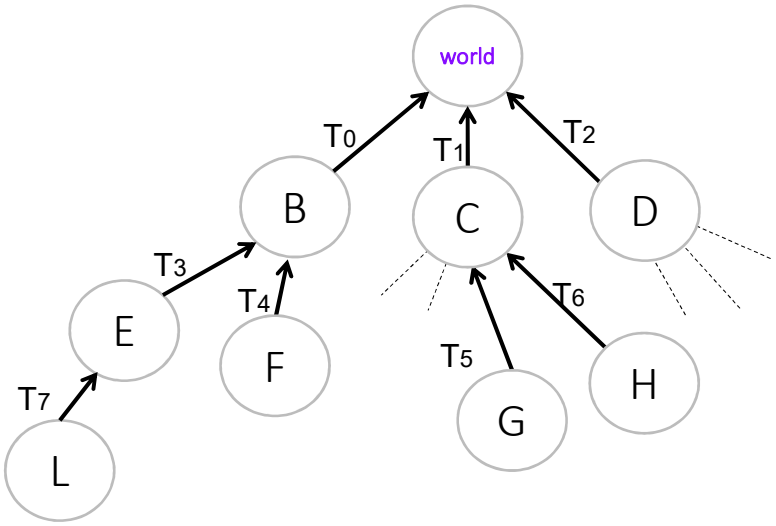
Nodes of a scene-graph in UNREAL ENGINE

USceneComponent

A node within a graph with:

- link to parent / children:
  - getParentComponents
  - getChildComponent(index)
- associated stuff to it:
  UPrimitiveComponent (subclass)
  - for models, physical bodies, etc
- Local Transform: (fields)
  - RelativeLocation , RelativeRotation, RelativeScale
- Global Transform: (methods)
  - GetComponentTransform() /* return transformation */

Drawing for the exercises



Exercises 1/2

- Give the *global transform* of node **L**
- I place a camera in node H:
  report the View Transform for the scene
- What does it mean to apply a translation (1,0,0) to L …
  1. in L Space (the local space of L)?
  2. in World space?
  3. in View Space?
- Say T7 is the identity, and the camera is in H:
  how to modify T7 to get the 1,2,3 cases?
- Find the origin of space E in space H, and viceversa
- A microfone is in (the origin of) node E, and a speaker is in (the origin of) node H. Find the distance from the mic to the speaker

Exercises 2/2

What is the new transform T'_7 which should subtitute T_7 if…

- …node **L** il reattached as a child of **D**, leaving its position in *world space* unaffected (e.g. by a scener, or a script)
- …node D is attached under node L, without affacting its world space position.
- …the object in node L must be moved 1 unit on the right in view space (camera is in node C)
- …the object in node L must be moved by by 1 unit ON ITS RIGHT (assume T_7 is currently the identity)
- …the object in node L must be displaced by a new transform T applied in post-transform space.

Note: these kind of problems are silently solved by Unity all the times (in the scripts & when user manipulates the the GUI)