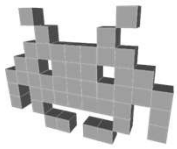
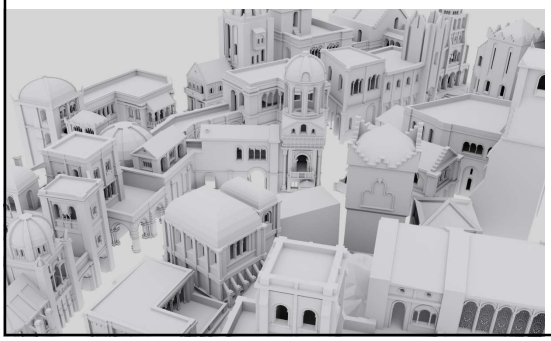
3D video games 2025/2026

the Scene Graph



Marco Tarini



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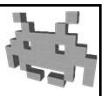
Course Plan



lec. 1: **Introduction**
lec. 2: **Mathematics** for 3D Games
lec. 3: **Scene Graph**
lec. 4: Game **3D Physics** +
lec. 5: Game **Particle Systems**
lec. 6: Game **3D Models**
lec. 7: Game **Materials**
lec. 8: Game **Textures**
lec. 9: Game **3D Animations**
lec. 10: **Audio** for 3D Games
lec. 11: **Networking** for 3D Games
lec. 12: **Interactive Agents** for 3D Games
lec. 13: **Rendering Techniques** for 3D Games

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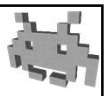
Recap: 3D Spatial Transforms



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

Thus, can be applied to any 3D thing (apply them to all positions directions etc …)

- Three components:
  - Scaling
  - Rotation
  - Translation

… modelling the State / Act of:

- Size / Rescale up (if > 1), down (if <1)
- Orientation / Rotate
- Position / Displace

can be "uniform" ("isotropic")
or not ("anisotropic", different factors in X,Y,Z)

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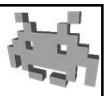
Recap: transformation associated to an object in the scene



- 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

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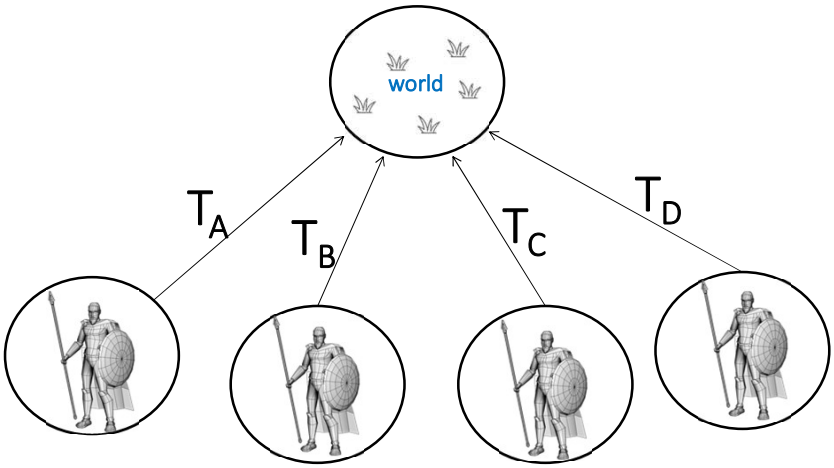
So far: the transform associated to each object goes from local space to world space



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Hierarchical scenes

- So far, we assumed that the transform of each object goes from local to global in one step
- In reality, scenes can be defined hierarchically
- That is, objects have sub-objects in them
  - a «city» is made of «houses» made of «walls» made of «bricks»

  - a «hat» sits on an «head» which is part of a «character» who sits in a «spaceship» moving across the «galaxy»
  - a car is a «hull» plus four «wheels»

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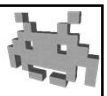
Objects in the scene



- Nodes in the scene graph host any object that is has a position, including…
  - Static Meshes
  - Animated meshes
  - The camera observing the scene
  - 3D GUI elements
  - Spawn points
  - Colliders (hit boxes)
  - Microphones
  - Sound emitters
  - Particle systems (the emitter)
  - Etc
- Each such object has its own associated transform
  - And, therefore, its own local space
  - The local transform goes from local space to space of the parent

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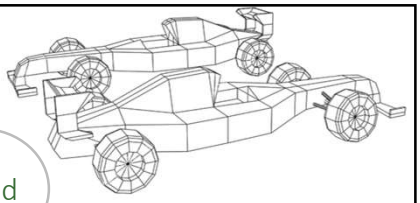
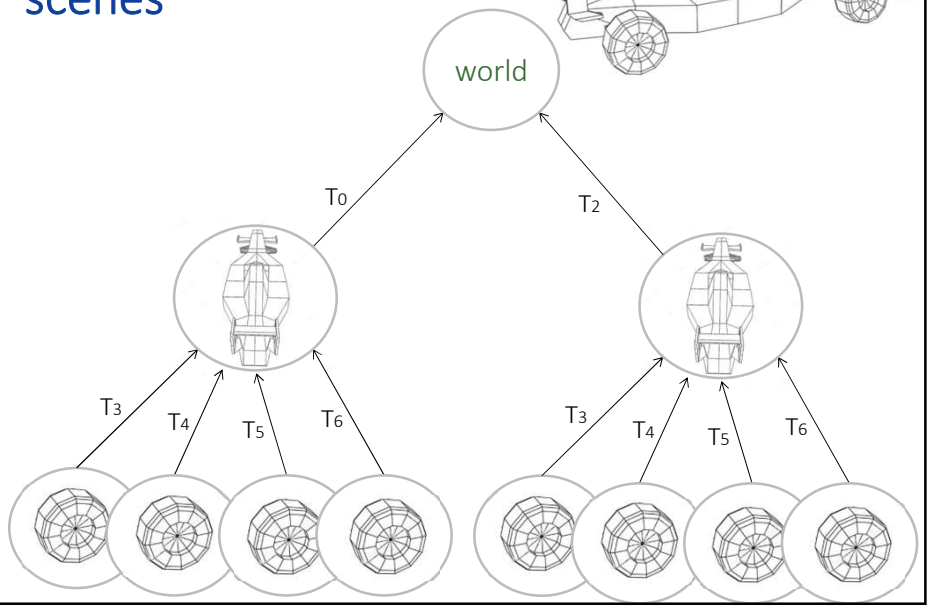
Hierarchical scenes





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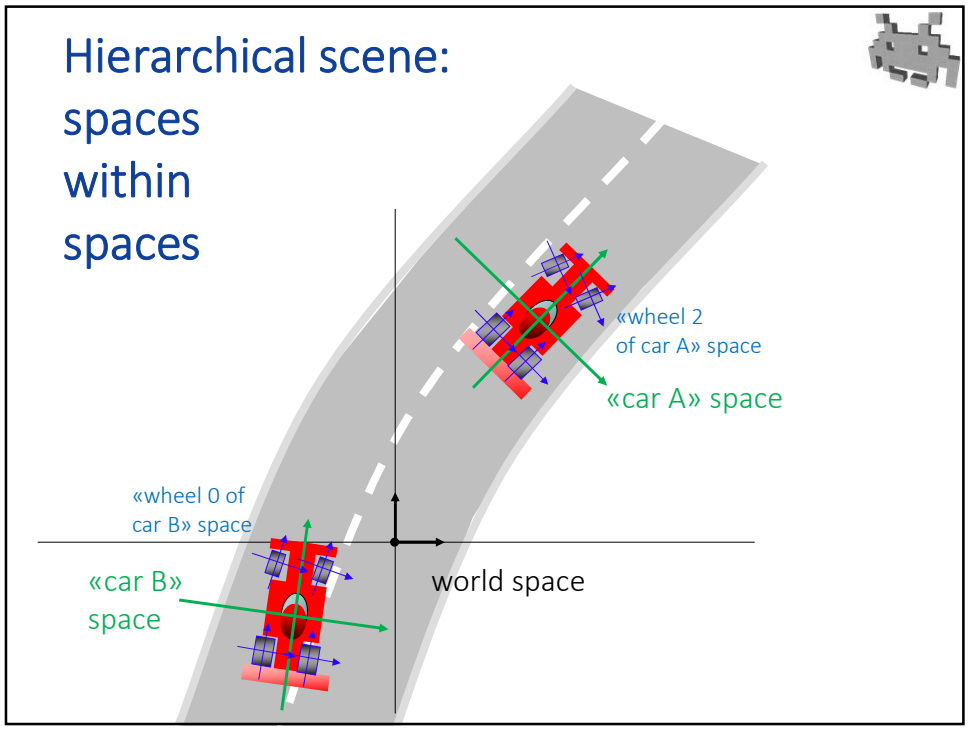
Hierarchical scene:
spaces
within
spaces
«wheel 2
of car A» space
«car A» space
«wheel 0 of
car B» space
«car B»
space
world space

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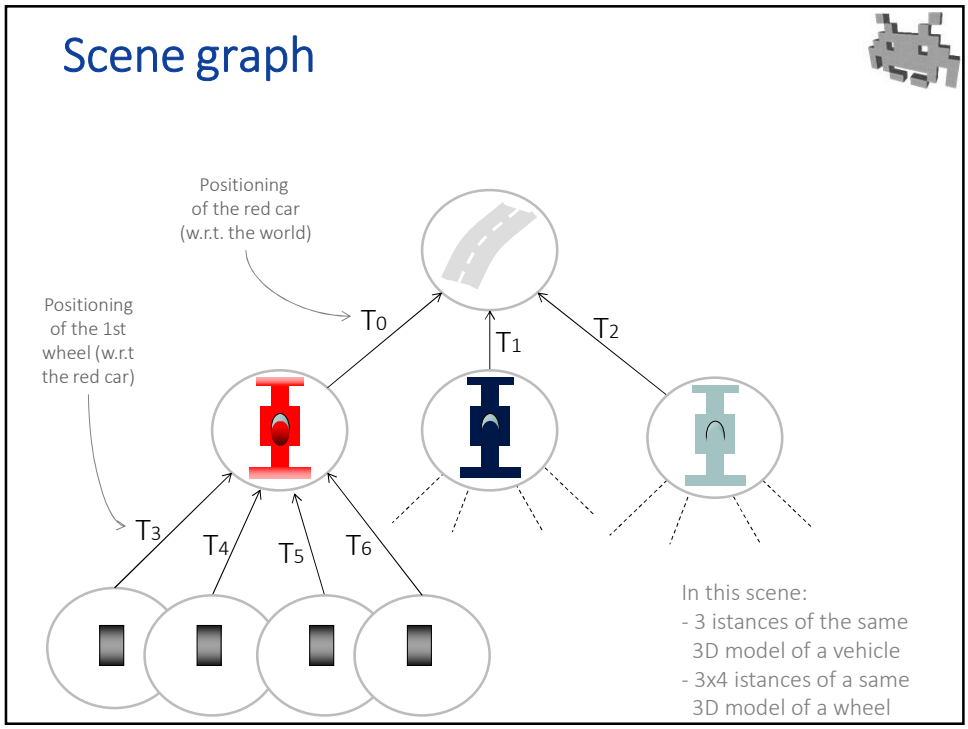
Scene graph
Positioning
of the red car
(w.r.t. the world)
Positioning
of the 1st
wheel (w.r.t
the red car)
T0
T1
T2
T3
T4
T5
T6
In this scene:
- 3 istances of the same
3D model of a vehicle
- 3x4 istances of a same
3D model of a wheel

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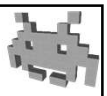
The scene graph (a definition)



A tree (i.e. a hierarchical structure)

- Each nodes has its own space (a reference frame)
  - The Local Space of that node
- To each node we associate:
  - Instances to… stuff:
    anything at all that has a place in the virtual scene:
  - 3D models, lights, cameras, virtual microphones
    spawn points, explosions, etc
- Root node: world space
  - Global Space = local space of the root
- To each arch: we associate the "local" transform
  - the transform going from the local space of the child node
    to the local space of the parent node

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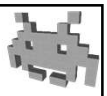
Local VS Global Transformations



- Local transform (a.k.a. «relative» transform)
  - from: the local space of a node
    to: the local space of its parent
  - Stored per object!
- Global transform (a.k.a. «absolute» transform)
  - from the local space of a node
    to the world space
    (which the "local" space of the root)
  - Procedurally obtained/defined by:
    compositing all local transforms from node to root
- benefit: changing the transform associated to a node affects its entire subtree

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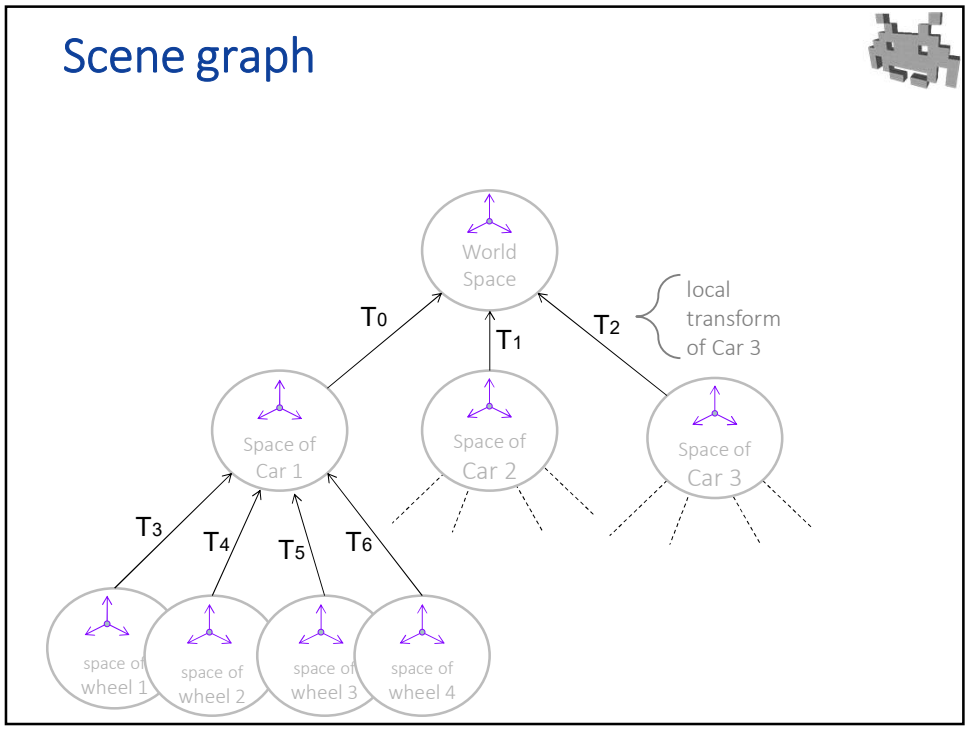
Scene graph
World Space
T0
T1
T2
local transform of Car 3
Space of Car 1
Space of Car 2
Space of Car 3
T3
T4
T5
T6
space of wheel 1
space of wheel 2
space of wheel 3
space of wheel 4

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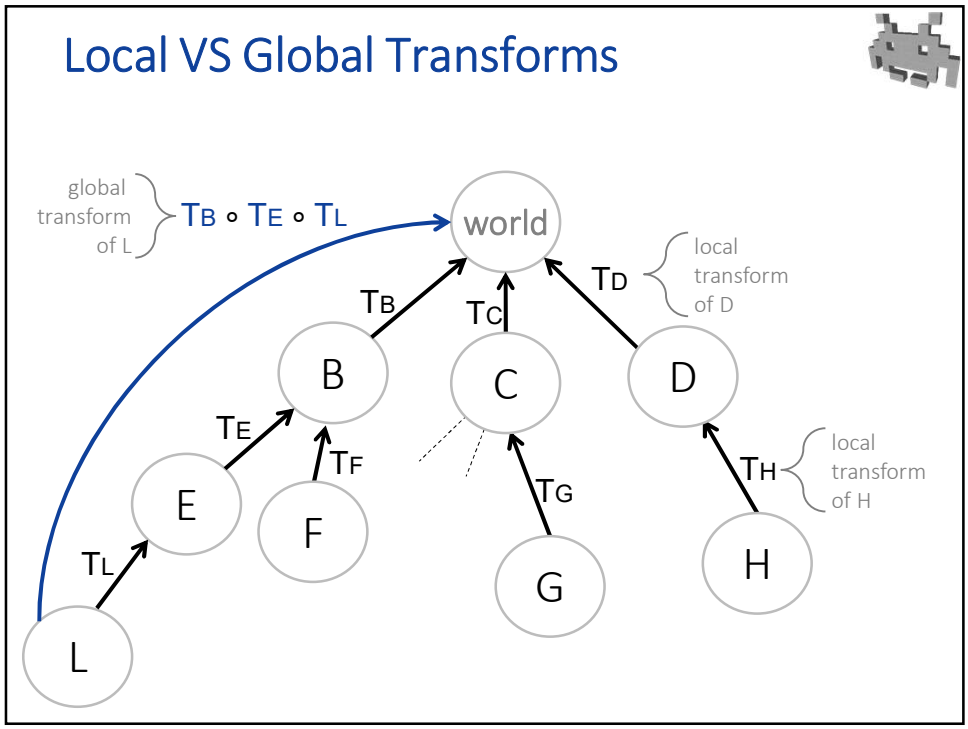
Local VS Global Transforms
global transform of L
TB ∘ TE ∘ TL
world
TB
TC
TD
local transform of D
B
C
D
TE
TF
TG
TH
local transform of H
E
F
G
H
TL
L

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