3D Video Games

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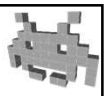
Università degli Studi di Milano
2025/2026

- Core techniques used in modern 3D games
- A well-established set
  of specific methodologies
  used in most 3D games

2

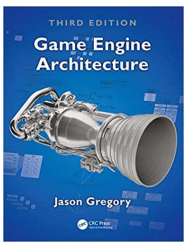
About this course: webpage



- Follow the link from Ariel
- or
  - Search for my name: Marco Tarini
  - Land on my unimi page
  - Follow 3D Videogame link
- or
  https://tarini.di.unimi.it/teaching/3DVG2026/

5

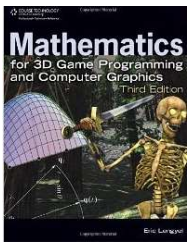
About this course: Potentially useful textbooks



Game Engine Architecture

Jason Gregory

Complete (notes on:
software tools, software eng., AI prog, CG prog, math, game design...)



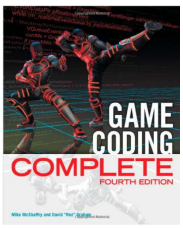
Mathematics for 3D Game Programming and C.G. (3rd ed)

Eric Lengyel

Good coverage of 3D math,
(and, CG pipeline, geometry + transforms, raytracing, visibility, physic sims, semplice geom processing...)

6

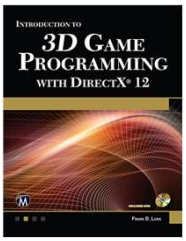
Other relevant books



Game Coding Complete (4th ed)

Mike McShaffry,David Graham

Practical approach
(sometimes not fully up to date)
Stress on coding asoect, software eng
(e.g. memory managment).



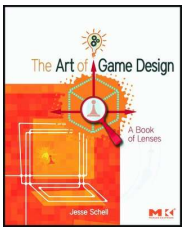
Introduction to 3D Game Programming with DirectX 12

Frank Luna

Rendering / GPU
(basically, Computer Graphics for games)

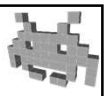
The Art of Game Design

Jesse Schell
not technical, focus on design!



7

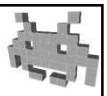
About this course: the exam



- Preliminary Written Test
  - Moodle
  - Closed and short open questions
  - Mini-problems
  - Definitions.
- Oral Exam
  - Covers the entire lectures
  - Procedure: I roll a die, 1-24
    Ask about respective lecture

8

About this course: Personal projects



- There is no project in this course

…but…

- Completely optional
- Not part of grading
  - No extra point
- Not an official part of the course in any sense or form
- Just an occasion to have fun

- You are encouraged to experiment with a game engine
- If you do have an ongoing project which is a 3D Videogame, maybe share your experience!

12

About this course: the “game of the week”

After every Monday lecture
(including today)

- Completely optional
- Not part of grading
  - No extra point
- Not an official part of the course
  in any sense or form
- Just an occasion to have fun

13

About this course: Little Extra

- C++ Coding
  3D Math
  - After Monday lecture
- Bring your own laptop
  - Learn C++
  - Learn math for 3D basics

- Completely optional
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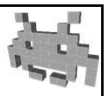
14

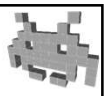
A 3D Video Game



- A very peculiar kind of Software
  - complex
  - in between art and technology
  - “Efficiency is KING”

16

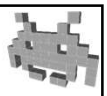
Game Categories: according to gameplay



- Puzzle game
  - Color matching
  - Hidden object
  - Trivia game …
- Action game
  - Beat’em up
  - hack’n’slash
  - Fighting
  - Pinball
  - Platform
  - Maze
  - Shooter
    - FPS
    - MMO FPS
    - LightGun
    - Shoot’em up (shumps)
    - Rail shooter
    - 3rd person
- Action-Adventure
  - Stealth
  - Survival horror
  - Exploration
  - PoP / Tombrider
- Adventures
  - IF - Interactive Fiction
  - Real time 3D adv
  - Point and click
- Board game
  - Card game …
- Strategy
  - 4X
  - RTS
  - Strategy MOBA / MMOG
  - Action-RTS
  - Tower defences
- Vehicle simulation
  - Driving simulator
  - Flight simulator
    - Amateur
    - Combat
    - Space …
  - Racing game
  - Vehicular combat
- Role-playing games
  - RPG (eastern, western)
  - Sandbox RPG
  - MMOPRG
  - Roguelikes
  - Action RPG
- Sport games
  - Soccer / Football / …
- Simulation / management

17

Categories: according to player types



casual games vs hard core games

18

Categories: according to platforms

- Arcade
- PC stand-alones
  - Aka “desktop app”
  - Win, Mac, Linux…
- Console
  - Wii, PS, XBox …
- Browser: game = web app
  - html5, webGL, unity, flash…
- Mobile devices
  - Android, iDevices, PSP …

20

Categories: according to developer

Independent games

- No/tiny publisher:

Mainstream games

- Big publisher

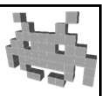
21

What does a video-game publisher do?

- fund developments
  - including licences
- distribution
- marketing
  - ads, launch, market surveys...
- packaging, manuals
- localization

High risk!

22



Categories: according to developer

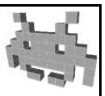
Independent games

- No/small publisher
- Low starting $
- Small Dev-Teams
- + freedom +novelty
  - (traditionally)
- In need of alternatives for:
  - Funding
    e.g.: Crowd funding
    - see indiegogo.com, kickstarters.com, …
  - Distribution
    - e.g.: steam, popcap, apple store…

Mainstream games

- Big publisher
- Big $ per project
  - (at times, mega-$'s)
- High quality: a must
- Large Dev-teams

23



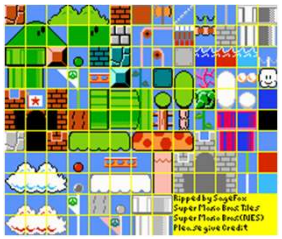
Categories: 2D or 3D?

2D games

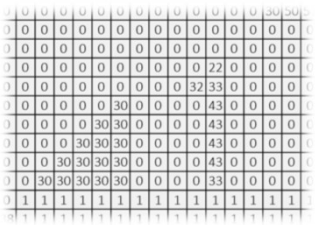
- Sprites + Tilemap

3D games

- 3D Models + 3D Scenes + etc…



TileSet

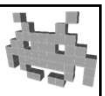


TileMap

Sprites

24

Categories: 2D or 3D?



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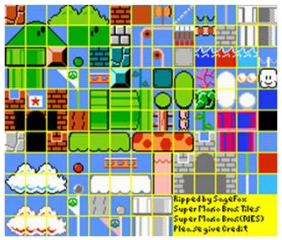
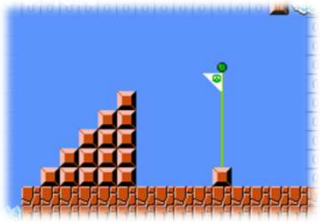


TileSet

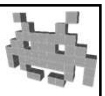


TileMap

Sprites

25

Categories: 2D or 3D?



2D games

- Sprites + Tilemap

3D games

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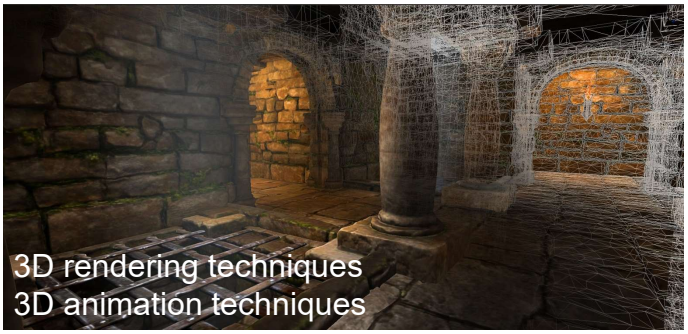
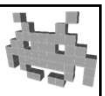


26

Categories: 2D or 3D?



2D games

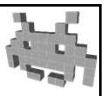
- Sprites + Tilemap
- Techniques:
  - Blitting
  - Tilemaps
    - and 2D scrolling
  - Sprite support
    - sprite collision-detection
    - 2D transform
  - (2D physical engines)

3D games

- 3D models + 3D Scenes
- Techniques :
  - 3D Modelling
    - Scenegraph, models
  - 3D Real time rendering
    - 3D transform
    - lighting
  - 3D animations
    - Kinematics, motion capture, model animations…
  - 3D phyisical simulations
  - 3D sound localization

27

Categories: 2D or 3D?



2D games

- Sprites + Tilemap
- Tools:

HTML5, Flash, Allegro, NEO GEO, GameMaker: Studio, …

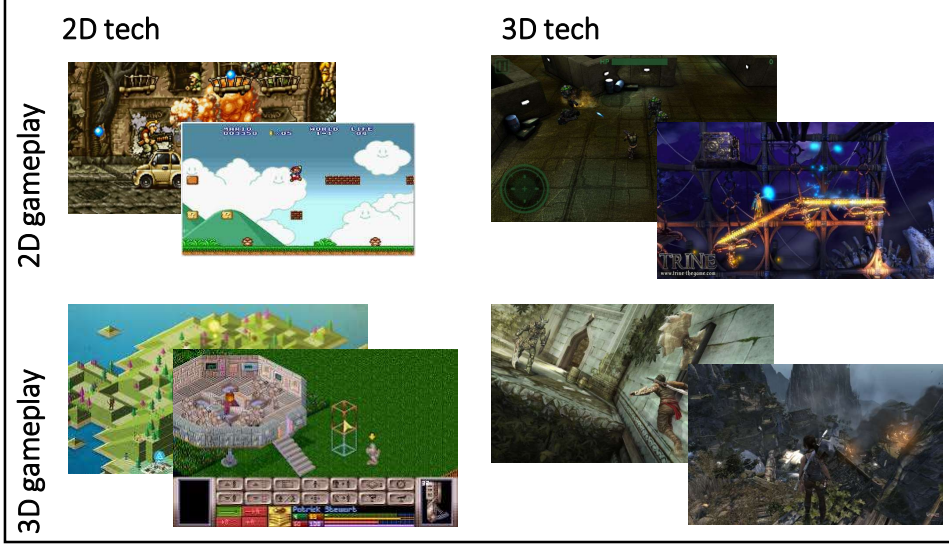
3D games

- 3D Models + 3D Scenes
- Tools:

OpenGL, Microsoft DirectX, OpenGL ES, blender game engine, WebGL, UNREAL ENGINE, unity, gameplay, OGRE, Urho3D, …

28

Note: we are interested in the tech not the gameplay



29

The academic side: conferences around Video Game Dev

- SIGGRAPH
  - ACM Special Interest Group
- i3D
  - Interactive 3D
- GDC
  - Game Developers Conference
- E3
  - Electronic Entertainment Expo
- PAX
  - Penny Arcade Expo

33

3D Video Games

40 y

Battlezone – Atari 1980

Unreal Engine V – 2020

34

Course Plan

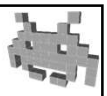
2h

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 ●

35

Course Plan

☆ = 1 CFU (8h)



lec. 1: Introduction ●
lec. 2: Mathematics for 3D Games ●●●●●
lec. 3: Scene Graph ●

★★ bases

lec. 4: Game 3D Physics ●●●◖ + ◗●
lec. 5: Game Particle Systems ◖

lec. 6: Game 3D Models ◗●
lec. 7: Game Materials ●
lec. 8: Game Textures ●◖

★ appearance

★★ computer animation

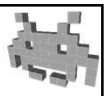
lec. 9: Game 3D Animations ◗●●

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 ●

★ "bridge" lectures

36

Game Engine: tasks



GRAPHICS
PHYSICS
ARTIFICIAL INTELLIGENCE
SOUND
SCRIPTING
NETWORKING
GUI + INTERFACES
ASSET MANAGEMENT
...

37

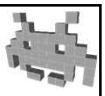
Game Engine

- A game SW suite which deals with a set of common tasks:
  - Handling of the 3D Scene
  - Renderer
    - Real time transform + lighting
    - Models, materials …
  - Physics engine
    - (soft real-time) Newtonian physical simulations
    - Collision detection + response
  - Networking
    - e.g., LAN via UTP…
  - 3D Sound-rendering, Sound mixer
  - Handling of input devices
  - Main event loop, timers, windows manager…
  - Memory management
  - AI module
    - Common solutions to many common AI sub-problem, e.g., routing
  - Localization support
  - Running scripts
  - GUI (e.g., via interactive HUD elements)

Animations
scripted or computed

39

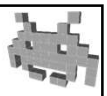
Implement once, use many times



- Still possible to make games completely from scratch (zero reuse), but increasingly rare.
  - Even many projects/series started this way then switch to a game engine
- Game-engines take care of many common functionalities needed by different games.
  - eg: Unity, Unreal Engine, GameMaker: Studio, Adventure Game Studio
- But
  - Reuse = constraints
  - Zero reuse → maximal freedom

41

Engines which we will *occasionally* refer or adopt for demonstration



OR

43

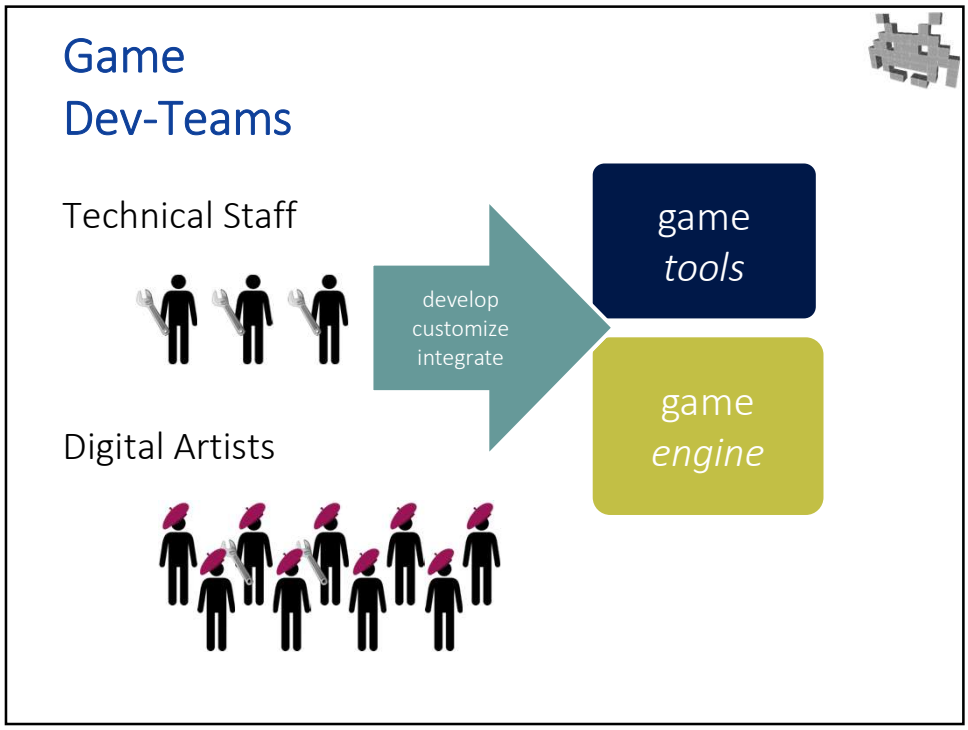
Game Dev-Teams

Technical Staff

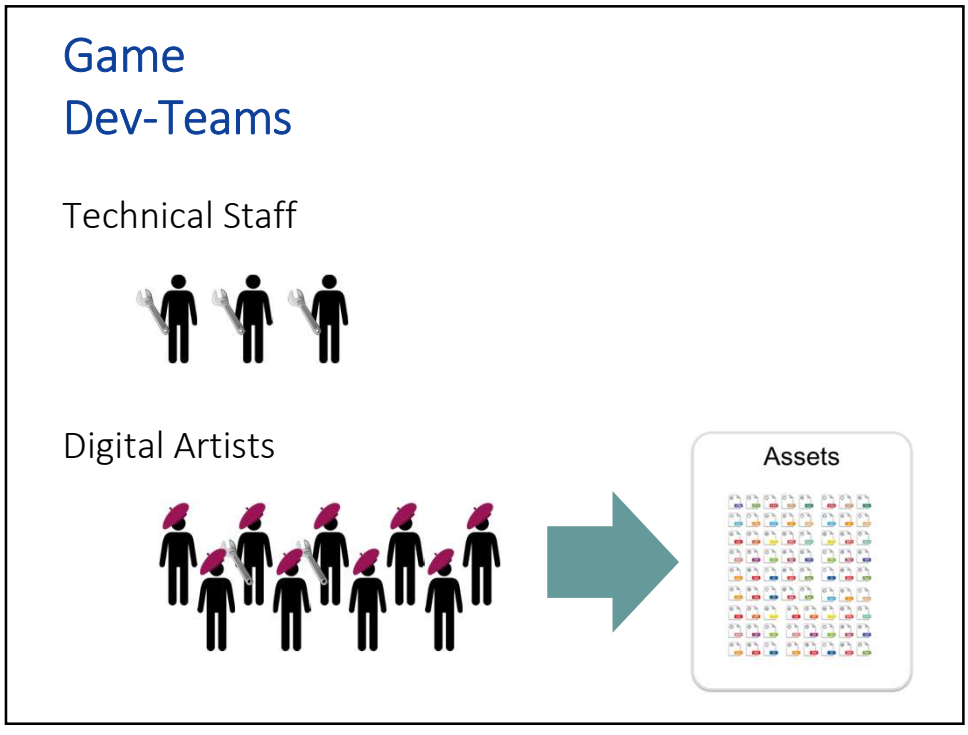
Designers

Digital Artists

44


Game
Dev-Teams
Technical Staff
develop
customize
integrate
game
tools
game
engine
Digital Artists

45

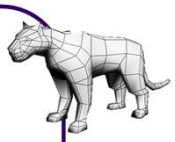

Game
Dev-Teams
Technical Staff
Digital Artists
Assets

47

Game assets

(*aka* game contents)

- 3D data
  - models
  - textures
  - materials
  - shaders
  - animations
  - collision objects
  - scenes
  - *etc*



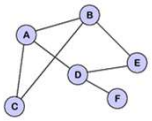
- audio
  - music
  - sound fxs
  - ambient sounds
  - voice overs
  - *etc*

- video
  - baked cut-scenes, intros, *etc*

- 2D art
  - screen splashes
  - backgrounds
  - GUI / HUD elements
  - [sprites & tile-sets ?]
  - fonts
  - *etc*

- text
  - dialogues trees
  - messages
  - translations
  - *etc*

- etc:
  - scripts
  - stats / tables
  - levels [& tile-maps?]
  - *etc*



49

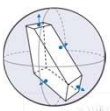
Game assets: the 3D subset

- 3D Models
  i.e. tri-meshes with:
  - per vertex attrib
    - normals, color, AO, ...
  - LODs
  - "uv-mapping"
  - keyframes
    - cyclic animations
    - face-morphs, ...
  - "skinning"

- Materials
  - lighting model stats / flags
  - textures
    - RGB maps
    - normal maps
    - alpha maps ...
  - shaders
    - vertex, fragments, ...

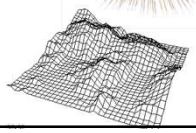
- Animations
  - blend shapes
  - skeletal animations
  - kinematic animations
  - geometry caches
  - skeletons (rigs)

- Geometric proxies
  - hit-boxes
  - bounding objects
  - AI-meshes



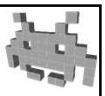
- Particle effects

- Environments
  - scene-graphs
  - skydomes
  - 2.5D terrains



50

GENERAL TERMINOLOGY



A general concept

we will be encountering it again and again

ASSET / STORED

- Build during the dev of a game
  - « it is designed »
  - « it is hand-modelled »

👍 quality (usually)
- (if artists are good)

👍 artistic control
- by the digital artist

- costs space (RAM, DISK…)

VS

PROCEDURAL / GENERATED

- Produced during game execution on-demand
  - « it's a procedure »
  - « it's dynamically generated »

👍 variations
- which is linked to *replayability*

👍 flexibility
- auto-adapts to the context

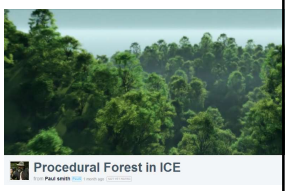
- costs computation time (CPU, GPU…)

51

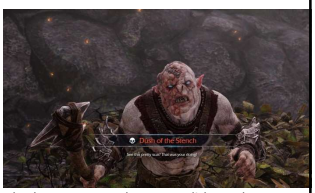
Procedural generation In games

For example
- Procedural levels / missions
- Procedural Terrain
- Procedural AI
- Procedural «Bosses»
- Procedural Scenes
- Procedural Models
- Procedural Textures
- Procedural Animations (physics)
- Procedural Music …

Rogue, Michael Toy et al, 1980




a roguelike


Shadow Over Mordor, Monolith Prod., 2014

Minecraft, Mojang, 2009

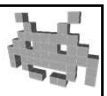
Elite, Acornsoft, 1984


Left 4 dead, Valve, 2008


Rescue the beagles, 16x16, 2008

52

Course Plan



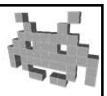
lec. 1: **Introduction**
lec. 2: **Mathematics** for 3D Games
lec. 3: **Scene Graph**
lec. 4: Game **3D Physics** + procedural
lec. 5: Game **Particle Systems**
lec. 6: Game **3D Models**
lec. 7: Game **Materials**
lec. 8: Game **Textures**
lec. 9: Game **3D Animations** as assets
lec. 10: **Audio**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

computer animation

54

GENERAL TERMINOLOGY

«Baking», «Baked» / «Pre-baked»



italian: "cuocere (al forno)"

once and for all, producing one asset (otherwise, it's caching)

: Storing *for good* the result of a procedural generation, for later use

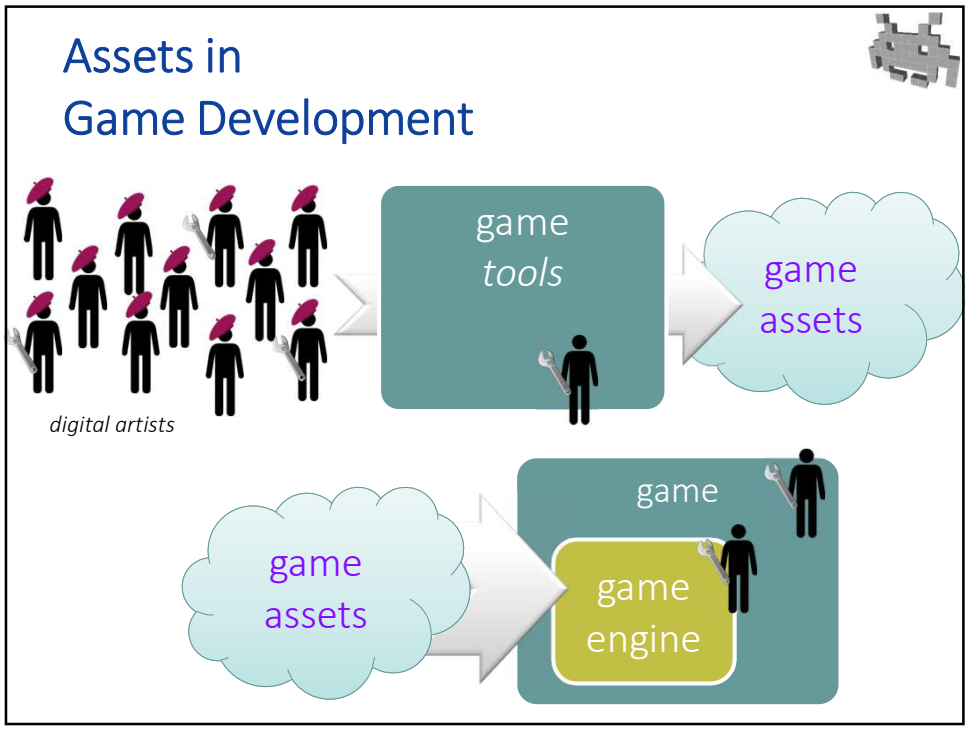
often, (a refined versions of) the ones normally employed in real time

e.g.: a "baked light-map", a "baked animation"…

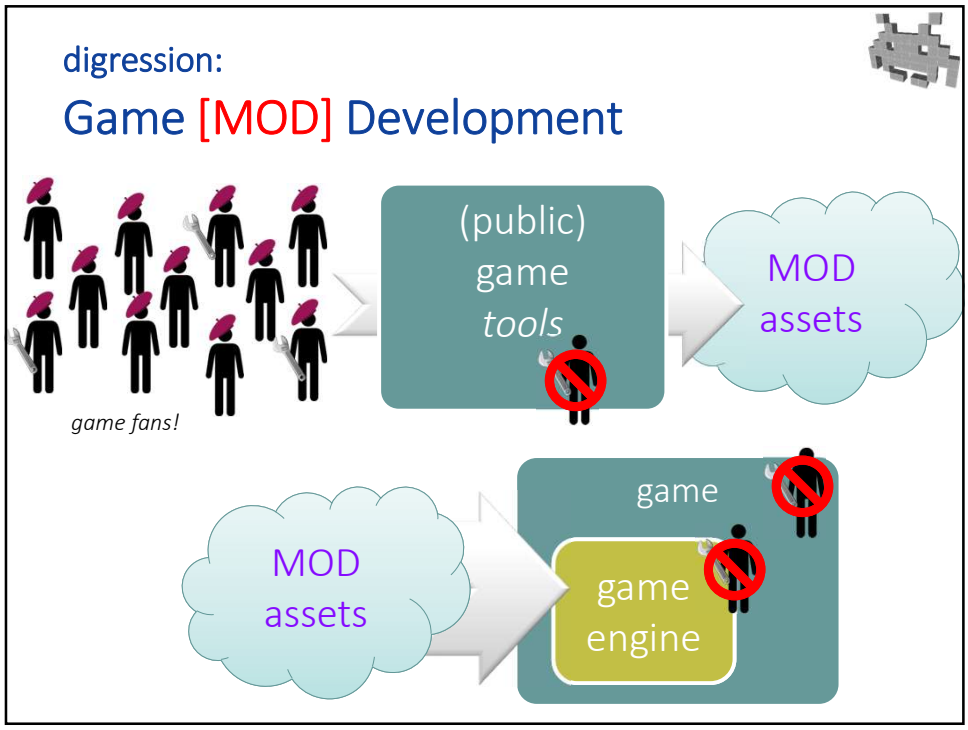
We gain:
- time (CPU / GPU workload)
- almost total independence from computation complexity ! → less compromises, more quality

We pay with:
- space (on disk , Ram , GPU RAM)
- loss of flexibility (all the parameters used by the computation are frozen)

55


Assets in
Game Development
digital artists
game
tools
game
assets
game
assets
game
game
engine

56


digression:
Game [MOD] Development
game fans!
(public)
game
tools
MOD
assets
MOD
assets
game
game
engine

57

GENERAL TERMINOLOGY

How «hard-wired» (or «hard-coded») is a given-video game feature?

- Where is it implemented?

in HARDWARE (eg. on the GPU)	in the GAME ENGINE	in the code of that video-game	in a script (or similarly controllably by an asset)

more «Hard-Wired» ← → less «Hard-Wired»

- Who can modify it?

The Hardware vendor (> platform dependence!)	the Game Engine dev-team	the tech part of the video-game dev-team	the artists (e.g. level designers); the modders

58

GENERAL TERMINOLOGY

How «hard-wired» / «hard-coded» is a given-video game feature?

More Hard-wired	Less hard-wired
👍 more efficiency	👍 ease of maintenance
👍 more scalability	👍 more customizability
👍 more reuse	👍 more flexibility

59