Game Engine Programming

GMT Master Program
Utrecht University

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Course code: INFOMGEP
Credits: 7.5 ECTS

Lecture #4

Game engine architecture

History

- At the beginning of game programming, the concept of game engine did not exist
  - software was specialized for application and hardware
- Now game structure is fully featured, reusable and kit-oriented
  - robustness improved in long term
  - faster to develop new games
  - earn money by selling engines
  - but look alike games

History

- The term game engine arose in the mid 90's
  - in reference to the first FPS games (*Doom* and *Wolfenstein*)
  - separation between software components, art assets, game worlds and game rules

Doom - Id Software

Wolfenstein - Raven Software

History

- In the end 90's, games are designed with reuse and modding
  - examples: *Quake 3 arena* and *Unreal*
  - customable via scripts
  - secondary revenue for the studio: creating middleware for game industry is viable

Quake 3 Arena - Id Software

Unreal – Epic Games

What is a game engine?

- Separation between game and its engine is blurry
  - depends on the development decisions
  - engine should be reserved to describe the reusable parts of a game
- The perfect virtual game engine has not yet been created
  - always requires adjustments to the content
  - genre and platform oriented which is useful if you find the right one for your goals
  - but in the right way thanks to ever-faster hardware allowing to do more in the same amount of time

What is a game engine?

- Architecture patterns of components are emerging
  - graphics and rendering
  - collision and physics
  - animation and AI
  - audio, input and resources managers
  - networking and multiplayer
  - scripting and data-driven systems
- Simplify development process
- Run on multiple platforms

Typical game team

- Engineers
  - design and implement the software (you!)
- Artists
  - produce visual and audio content
- Game designers
  - define the gameplay: story, goals, game world ...
- Producers
  - schedule and human resources
- Publishers and studios
  - own and distribute the product
- Other staff
  - marketing, administrative, IT

Engines across genres

- Engines are typically genre specific, but large overlap
  - user input, visual rendering ...
- Example
  - *Unreal Engine* (originally for FPS) used in
    - *Grimm* (Spicy Horse): action-adv.
    - *Gears of War* (Epic Games): TPS
    - *Speed Star* (Acro Games): race

Genre technology requirements

- FPS
  - efficient rendering, physics-based animation and AI of NPCs
- Platformers & TPS
  - dynamic world, high fidelity animation of main character, camera collision system
- Fighting games
  - animation database, accurate user input, character animation
- Racing games
  - LoD, rendering, rigid body physics and deformations
- Real-time strategy (RTS)
  - crowds, evolving environment, complex AI
- Massively multiplayer online games (MMOG)
  - intensively use of network, data optimization, memory and account management (persistent world), VoIP service
- And more: sport games, RPG, serious games, simulations, puzzles and cards, web-based games ...

Commercial game engines

- Id Software's Quake Engine
  - started in 1992 with Wolfenstein
  - freely available open source (Quake I and II)
  - in C, a bit outdated
- Epic Games' Unreal Engine
  - started in 1998 with Unreal
  - richest features and easy-to-use tools in UE3
- Valve's Source Engine
  - drives Half-Life and sequels
  - complete graphics capabilities and tool set
- Microsoft's XNA Engine
  - development platform
  - to easily create and share games
  - in C#, for PC and Xbox360

Commercial games engines

- C4 Engine
- Torque Game Engine
- 3DGame Studio
- TV3D SDK
- Leadwerks Engine
- Unity
- ShiVa Engine
- Esenthel Engine
- DX Studio
- NeoAxis Engine
- *and more*

Torque

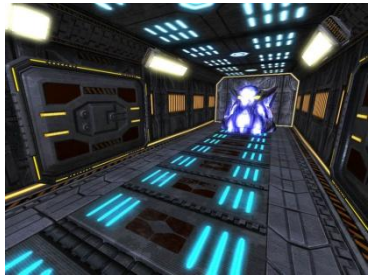
C4

TV3D

3DGame

Esenthel

NeoAxis



Unity

Leadwerks

Other engines

- In-house engines
  - many studios use their own engine
    - Ex: Ubisoft's Anvil
  - often platform and genre dependent
- Open source engines
  - GPL and LGPL license
  - Examples
    - Panda3D
    - Yake (OGRE 3D)
    - Crystal Space
    - Blender game
    - Irrlicht
    - *and more*

Anvil

Panda3D

OGRE

Crystal Space

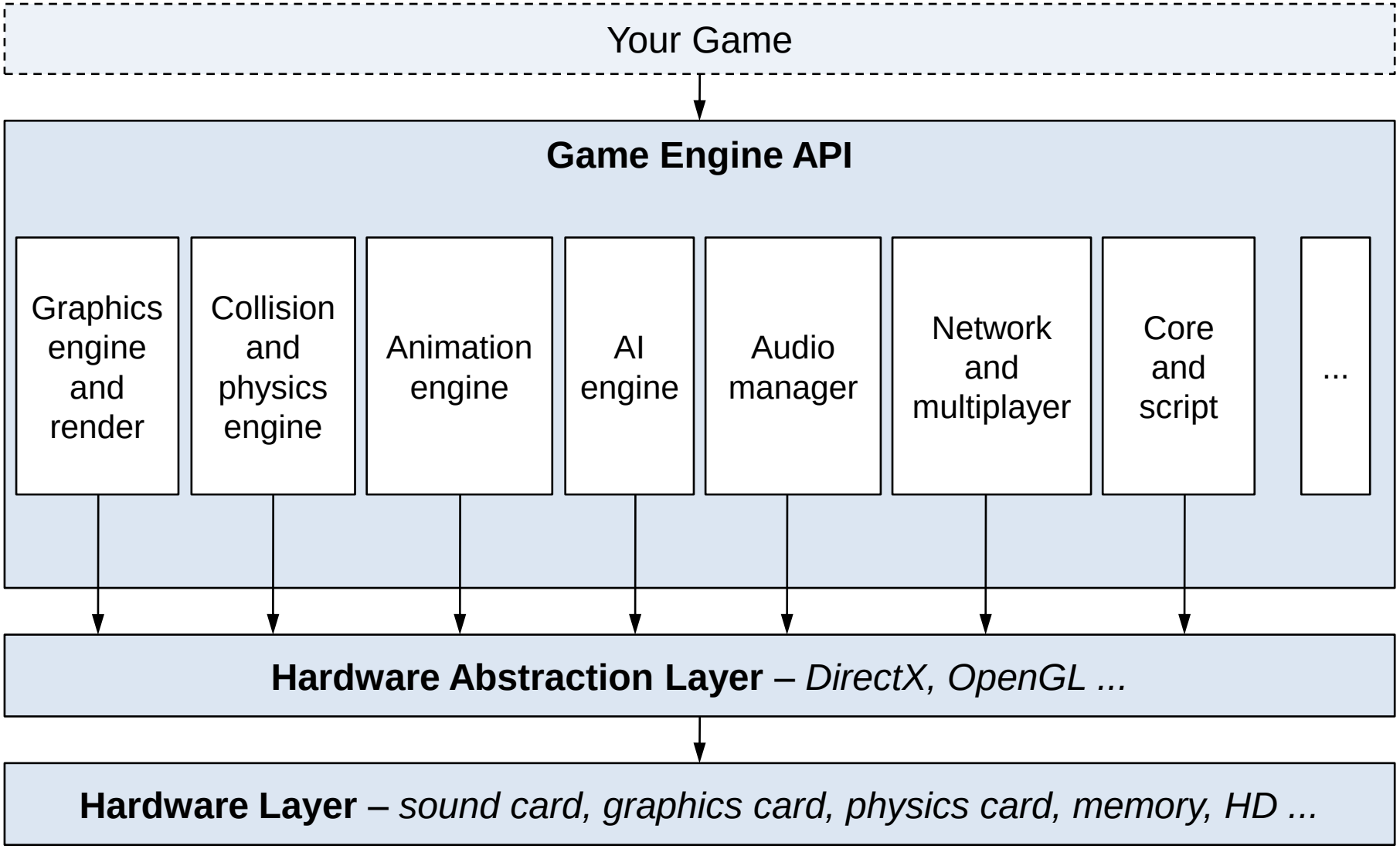
Blender

Irrlicht

Use existing game engine or not ?

- Why use an existing game engine
  - Less development time required
  - Less testing and debugging
  - Many features directly available
  - Better focus on the game design
- Why not use an existing game engine
  - No control over the implementation of features
  - Adding features not yet in the game engine might be time consuming
  - Dependent on other licensing scheme for release
  - Other libraries/toolkits linked with the game engine (physics, AI…)

Runtime engine architecture



Hardware layer

- Physical
  - Graphics card
  - Sound card
  - Physics card
  - Input devices (keyboard, mouse, joysticks, game pads, steering wheels, remote controllers, cameras …)
- Drivers
  - Low level interface

User Interface

- Rather simple
  - Monitors input devices and buffers any data received
  - Displays menus and online help (can nowadays be very complex)
- Should be reusable, especially as a part of a game engine

Graphics engine

- Most graphics engine are built on top of hardware interface libraries
  - Glide: 3D graphics SDK, outdated
  - OpenGL: widely used, multiplatform
  - DirectX: Microsoft's 3D graphics SDK
  - libgcm+Edge: PlayStation3 graphics interface

Graphics engine

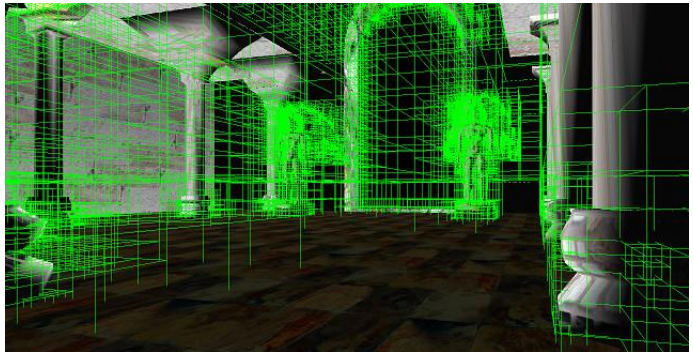
- Higher level interface, tuned to a particular graphics and game type
  - Sprite-based
  - Isometric
  - Full 3D
- Can deal with higher level modeling concepts
  - Sprites
  - Solids
  - Characters (articulated)
- Handles more complicated display aspects
  - Mini map
  - Multiple views
  - Overlays
  - Special effects

Rendering

- Graphics engine is used to model the data
- Rendering performs their visual feedback
  - depends on the graphics hardware (card) and graphics engine
- Takes care of
  - low level and optimized scene graph exploration and rendering
  - visual effects (particle, mapping, dynamic shadows, HDR effect, ...)
  - front end (HUD, menus, GUI, video)

Rendering

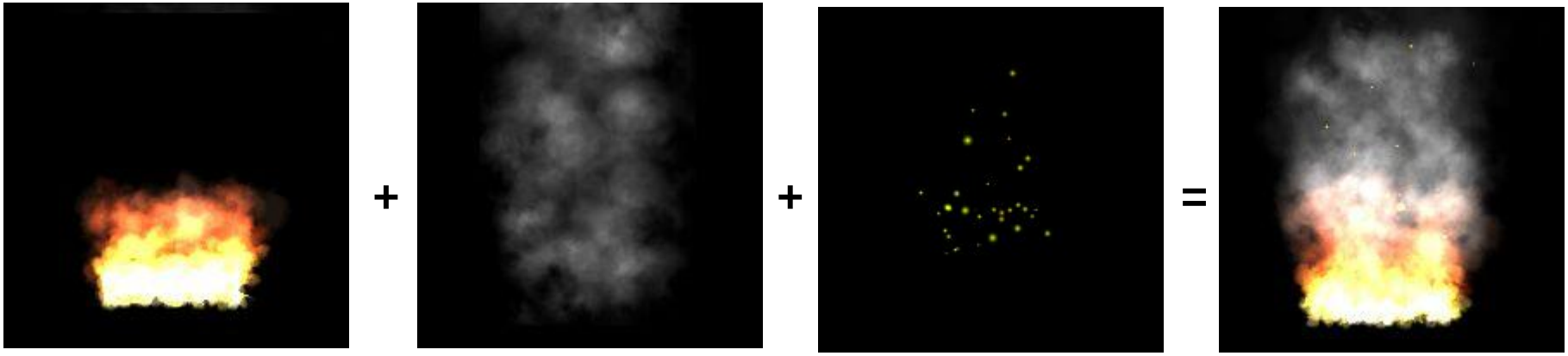
dynamic shadow (Cry Engine 2)



octree representation

HUD (Monkey Island 4)

particle systems



Collision and physics engine

- Handles the simulation of the world
  - Physical behavior (gravity, motion laws ...)
  - Collisions
  - Terrain changes
  - Ragdoll characters
  - Explosions
  - Object breaking and destruction
- Physics is more and more integrated into the gameplay and game subsystems
  - Physics-based animation
  - Interaction with objects using physics
- Limited or non-existent in simple games

Collision and physics engine

- Some SDKs
  - Havok
  - Open Dynamics Engine (ODE)
  - Tokamak
  - PhysX (Nvidia/Ageia)
    - software SDK
    - hardware card (PPU)

Havok (Diablo 3)

ODE (Call of Juarez)

PhysX card (Asus)

PhysX (Mafia II)

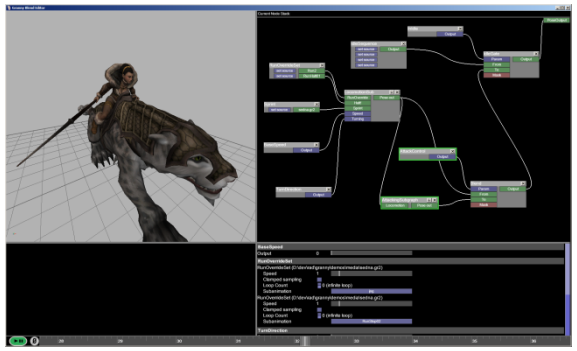
Tokamak (Hollow)

Animation engine

- Partially linked to physics engine
- Handles off-line
  - motion capture and retargeting
  - motion editing and annotation
- Handles real-time
  - sprite / texture animation
  - vertex animation by skinning
  - rigid body and skeletal motion
    - generation (ex: reactive character)
    - transition and blending (ex: walk to run)
    - adaptation (ex: reaching constraints, pushing, gazing)

Animation engine

- Animation packages
  - Granny, used in over 2,000 games
  - Havok Animation, extension of Havok SDK
  - Edge, for PS3
  - Endorphin (Maya plug-in) / Euphoria (real-time) include biomechanical models



Granny

Havok Animation

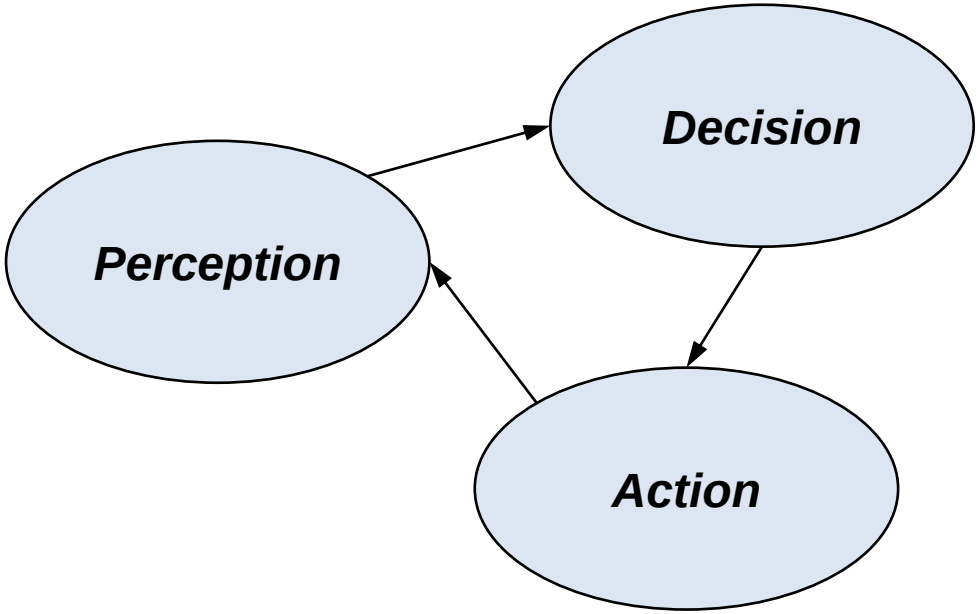
Euphoria

AI engine

- Behavior and interaction
  - dialogue (scripted or generated)
- Spatial displacements
  - obstacle avoidance, path planning
- Strategies
  - Hiding, attack / defense, grouping
- Decision making
  - scenario based or generated in real-time
- Crowd behaviors
  - simulation of panics, riots, high density areas

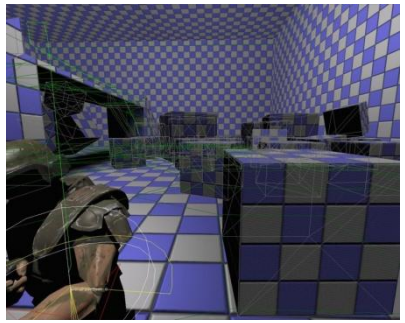
AI engine

- Agent-based approach including the loop
  - perception: senses input (view), dialogues...
  - decision: AI core, rules/learning process
  - action: execute (sequence of) operation(s)



AI engine

- Some AI engines
  - AI-implant (Presagis)
    - AI authoring and runtime software solution
  - Kynapse (AutoDesk)
    - customizable game-logic system
  - DirectIA (Masa)
    - generic game AI
  - SimBionic, AISeek,...



Conflict Zone (Ubisoft)

Audio manager

- As important as graphics in the game engine
  - Effects to enhance reality
  - Ambience
  - Clues about the gameplay
- Sound formats
  - wave (high quality, memory intensive, fast)
  - mp3 (high quality, compressed, slower)
  - midi (low quality, low storage, adaptable)
  - CD (very high quality, fast, limited to background music)

Audio manager

- Simultaneous sounds
  - Mixers
  - Buffer management
  - Streaming sound
- Special features
  - Positional 3D sound (Dobly Surround)
  - Adaptive music (DirectMusic)
- Some audio managers
  - Quake and Unreal: basics
  - XACT for PC and Xbox360
  - Electronic Arts' SoundRIOT
  - Sony's Scream used in PS3 titles
  - IrrKlang, OpenAL, FMOD …

Networking

- To allow multiple players to play together within a shared virtual world
  - Single-screen multiplayer
    - multi devices, one camera
  - Split-screen multiplayer
    - multiple HID and cameras
  - Networked multiplayer
    - multiple computers networked
  - Massively multiplayer
    - central servers, persistent world

Gauntlet (Atari Games)

Super Mario Kart (Nintendo)

Counter Strike (Sierra Studio)

World of Warcraft (Blizzard)

Networking

- Data have to be transferred between players/computers
  - efficiency is the key
  - memory management critical in MMOG
- Has a profound impact on the design of the game engine
  - on world modeling, rendering, HID, animation...
- Conversion from
  - single player to multiplayer is difficult
  - multiplayer to single player is often trivial
- Networking managers: RakNet, GNet, GNE

Core and script

- The core system usually implements
  - an event system to communicate between objects
  - a scripting system to model the game logic (no rebuilt of the program)
- Gameplay is implemented in the native language of the engine and/or with scripts
  - refers to world actions and rules, character abilities, goal and objectives of the game

Core and script

- Scripting languages in game engines
  - Advantages
    - Easy control of many (or all) features in the game engine
    - Scripting language often provides full OO control
    - Promotes data-driven design
  - Disadvantages
    - Performance
    - Development support tools
    - Learning curve

Core and script

- Common languages used for scripting
  - Python
    http://www.python.org

  - Lua
    http://www.lua.org

  - GameMonkey
    http://www.somedude.net/gamemonkey
  - AngelScript
    http://www.angelcode.com/angelscript

Core and script

- What belongs to scripting and what belongs to the engine?
  - Engine
    - Graphics
      - rendering
      - shadows/lighting
      - occlusion culling
    - Physics
      - dynamics
      - collision response
      - raycasting
    - AI
      - pathfinding
      - fuzzy controllers
      - planning
  - Script
    - Graphics
      - time-of-day
      - add/remove lights
      - loading/moving objects
    - Physics
      - object mass/friction
      - collision events
      - raycast events
    - AI
      - path selection
      - decision making
      - goals/objectives

Human interfaces devices (HID)

- To process the I/O from/to the player
  - keyboard, mouse, joystick/pad, controllers
- Driver of the hardware
  - get physical input
  - customizable mapping to actions
  - recognition of chords, sequences and gestures

Microsoft SideWinter 2

Sony PS3 joypad

Nintendo Wiimote

Sony PS Move controller

Microsoft Kinect camera

Profiling and debugging tools

- Game engines often integrates commercial or in-house tools to
  - time parts of the code
  - profile statistics in real-time
  - dump performance stats and memory use
  - control debug statements
  - record events and play them back

Data creation tools

- Not considered as game engine components
- 3D models / geometry data / animation
  - Maya, 3ds Max, Blender, SoftImage, ZBrush ...
- Audio data
  - Sound Forge, Audacity, ...
- Game world data and editor
  - Radiant (Quake), Hammer (Half-Life), UnrealEd (Unreal)
  - games provides more and more in-house world editor
  - very cheap way to extend the content of the game and make its life time longer
- Data are usually processed (simplified and encrypted) after exportation from in-house or commercial software and then loaded in-game

To go further – UU master courses

- Graphics engine and rendering
  - Geometric Algorithms, Computer Vision
- Collision and physics engine
  - Game physics
- Animation engine
  - Motion and manipulation, Computer Animation
- AI engine
  - Games and Agents, Intelligent agents, Common sense reasoning, Multi-agent programming
- Network engine
  - Algorithms and networks

End of lecture #4

Next lecture

The game loop