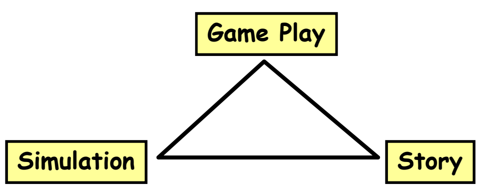
CMSC 498M: Chapter 2
Game Architecture

Sources:
- Lecture notes by M. Overmars from Univ. of Utrecht.

Overview:
- Basic elements of game design
- Game architecture – basic structural elements and relations
- Sample game program structure and timing
- Scene graphs

Basic Elements of Game Design

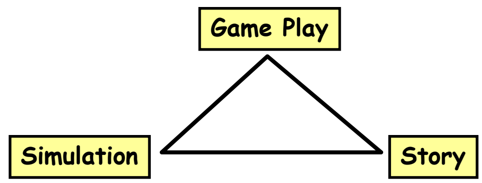
The Dimensions of a Typical Game:



Game Play: deals with materials, moves, rules, balance, and winning.
Simulation: deals with the internal mechanics of the virtual world.
Story: deals with the setting, storyline, immersion, dramatic effects and motivation.

Game Space:
- Game genre's differ in the **relative importance** of these elements.
- Where do your **favorite games** fit within this triangle?

Basic Elements of Game Design

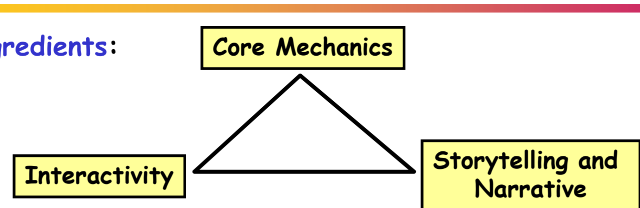


Some Thoughts:

- **Traditional games** tend to fall close to the **corners**.
- There is a tendency among **developers** to move towards the **center**.
- Is this desirable?
  - A **realistic** world simulation may interfere with **game play** and **balance**.
  - **Game play** emphasizes **player control** while stories emphasize **designer control**.

The Ingredients of a Game

Game Ingredients:



Core mechanics: The rules.

Storytelling and narrative: Storyline, dramatic effect and motivation, involvement.

Interactivity: How the player perceives the world and how he acts within it.

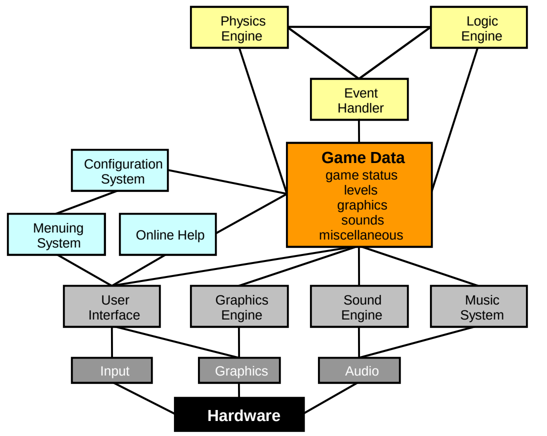
Example: First-Person Shooter:

Core mechanics: **What** is the effect of shooting?

Storytelling and narrative: **Whom** are you shooting at and **why**?

Interactivity: **How** do you aim? **How** does the target appear? **How** do you perceive the effect?

Game Software Architecture



Source: Mark Overmars

Architecture Elements: Low-Level

Hardware:

Physical:

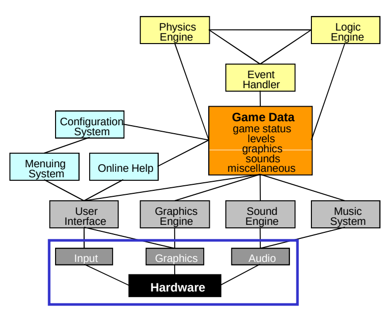
- Graphics card
- Sound cards
- Input devices (keyboard, mouse, game controllers, steering wheels)

Drivers:

- Low level interface

Hardware abstraction layer:

- DirectX/DirectSound
- OpenGL/OpenAL
- others …



Architecture Elements: Graphics Engine

Graphics Engine:

Higher-level interface:

Tuned to a particular graphics and **game type**:

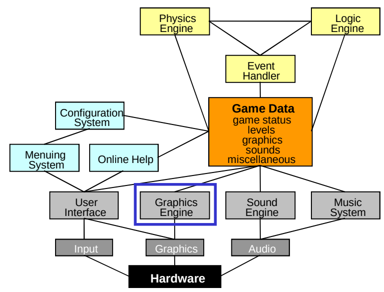
- sprite-based
- isometric view (fixed aerial viewpoint)
- full 3D

Rendering models:

- Sprites
- Solids
- Characters (articulated)
- …

More complicated display aspects:

- Mini-map
- Multiple views
- Overlays
- Special effects



Chapter 3, Slide 7

Architecture Elements: Sound Engine

Sound Engine:

Function of sound:

- Effects to **enhance reality**
- **Ambience**/**mood** (music)
- Clues about **what to do** (e.g., follow the voice of a friendly agent)

Sound formats:

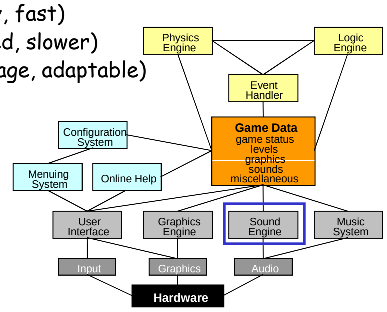
- **Wave** (high quality, lots of memory, fast)
- **MP3/OGG** (high quality, compressed, slower)
- **MIDI** (lower quality, very low storage, adaptable)

Simultaneous sounds:

- Mixers
- Buffer management
- Streaming sound

How to create:

- Get it from the **Web**
- **Record** samples and modify
- Build your own **music studio**!



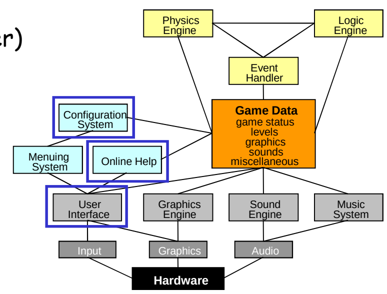
Chapter 3, Slide 8

Architecture Elements

User interface:
- Monitors **input status** (callbacks) and relays inputs to the **game data**.
- Displays **menus** and **online help**.

Configuration system:
- Adapt to **hardware specs** (requires choices)
- Adapt to **player preferences**
- **Player dependent** (stored by player)

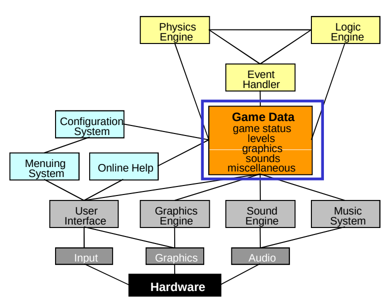
Online help:
- Players **never** read documentation.
- Screen **overlays**
- **Contents**:
  - Static
  - Context dependent
  - Player dependent



Architecture Elements: Game Data

Game Data: **"A game is a database with a fancy interface"**
- **Resources**
  - graphics models (sprites, characters)
  - sounds, music
  - images, backgrounds, video
  - text
- **Level description**
- **Game status**
- **Event queue**
- **User profile**

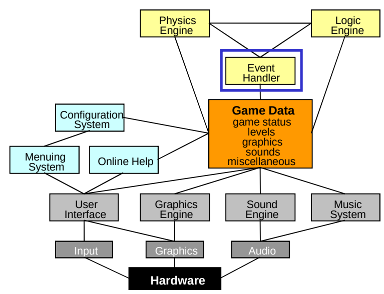
The game components **communicate** with the support components through the game data.



Architecture Elements: Events

Event handler:

- **Event-based**: (typically)
  - Events invoke **callbacks**.
  - Cause logic and physics engines to **change the game status**.
  - New game status is reflected **visually** (redrawing the scene).
- **Event Types**:
  - **User inputs**.
  - **Collisions**.
  - **Timers** (controlled by the logic).
  - Created by **game entities/objects**.
- **Game entities/objects**:
  - Entities have a **state**.
  - Can **react to/create events**.
  - Responses can be **complex** (AI).



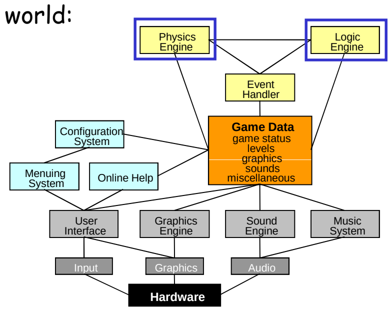
Architecture Elements: Logic/Physics

Logic engine:

- Handles all the **game play**.
- Enforces the **rules**.
- Contains the game **AI**.

Physics engine:

- Handles **physical simulation** of the world:
  - collisions
  - rigid-body simulation
  - waves in the sea
- Becoming increasing prevalent, even in **simple games**.
- Separation with logic engine is not always clear.



Simple Game Program structure

Initialization: (on entering a new level)
- Loading **resources** (art, sound, etc.)
- Intro screen
- Configuration and settings

Game loop:
- Process input **events**
- Receive network **messages**
- Update **time** step
- Run **AI** (planning) and **physics** (collision detection and response)
- Update game **entities/state**
- Send network **messages**
- Display

Finalization: (on exiting a level)
- Saving results/state
- Trailer

Timing

Based on the display's frame rate:
- Latency hiding (e.g., by pre-computing expensive operations)

Decoupling drawing and processing:

Semi-decoupled:
- Event processing cycles at a **fixed frequency** (may be **slower** than frame rate).
- Drawing occurs when **not busy** doing a cycle.

Fully decoupled:
- System does **small steps**, processing few events (and scheduling others for future processing).
- Drawing occurs when frame is **needed** and not inside a step.
- Game state must **always** be valid. (More difficult to implement.)

Maximizing GPU/CPU parallelism:
- Start graphics **early** so GPU is working in **parallel** with CPU, not waiting for it.

Scene Management/Scene Graphs

Scene Management:

Storing the various entities of your world for **efficient access** and **rendering**.

Motivation:

- **Culling**: Eliminating objects that are **not visible**, based on the current camera position.
- **Naïve solution**: Visit **all** the objects in your database and check them one-by-one. (Very inefficient.)
- **Better solution**: Store the objects in a **hierarchical structure**. Each node has stores a **bounding box** for all its descendents. If the bounding box is **not visible**, we can **eliminate** the entire subtree.

Scene Graph:

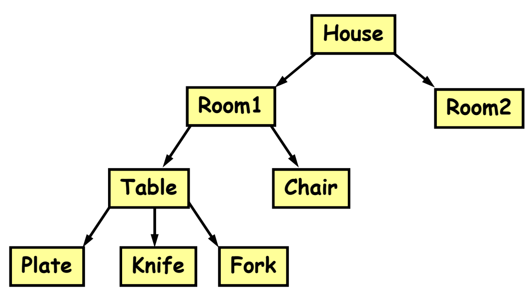
A **hierarchical** data structure for organizing geometric entities.

Scene Graph

Organization:

- **Leaves**: Store **individual** (primitive) objects.
- **Internal nodes**: Store **aggregate** objects, formed by grouping either primitive objects or other aggregates.

Example: A house with 2 rooms. One room has a table and chair. There is a place set at the table.

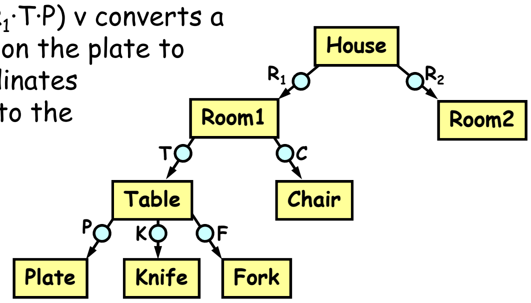


Scene Graph: Local Coordinates

Local Coordinates/Transformations:

- **Local Coordinate System**: Each object is represented relative to its own local coordinate frame.
- **Change of Coordinates**: Each link stores a transformation (4x4 matrix) that converts from the child's coordinate frame to its parent's frame.

Example: $(R_1 \cdot T \cdot P)$ v converts a vector v on the plate to its coordinates relative to the house.



Scene Graph: Compound Motion

Motion Transformations:

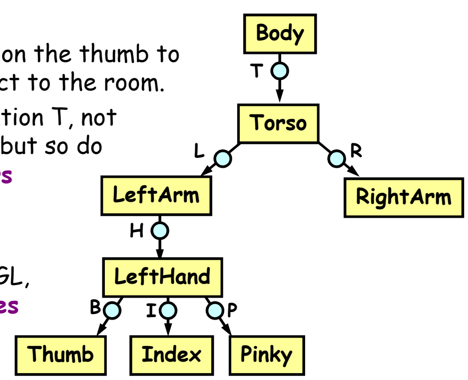
- **Motion**: These transformations can also be used to represent **compound motion**.

Example:

- (T·L·H·B) v converts vector v on the thumb to its coordinates with respect to the room.
- If we **change** the transformation T, not only does the **torso move**, but so do the **arms**, **hand**, and **fingers** (relative to the body).

Matrix Stack:

- Graphics APIs, such as OpenGL, provide a **stack of matrices** for drawing scenes based on scene graphs.



Scene Graph: Instancing and Cloning

Instancing:

We can create **multiple instances** of a single object by **sharing nodes**, but using **different transformations**.

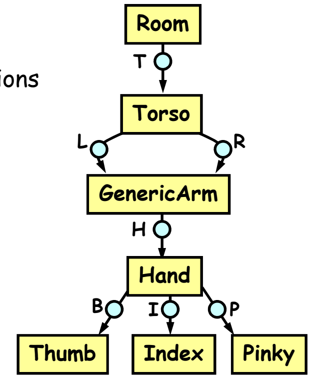
Example:

We generate only **one model** of the arm, but we use two different transformations (one of which involves reflection) to create **two instances** of this model.

Since only the L and R transformations differ, the two generic arms behave **identically** otherwise.

Cloning:

Makes a **copy** of a subtree. This allows the copy to behave **independently**.



Chapter 3, Slide 19

Scene Graph: Model Switching

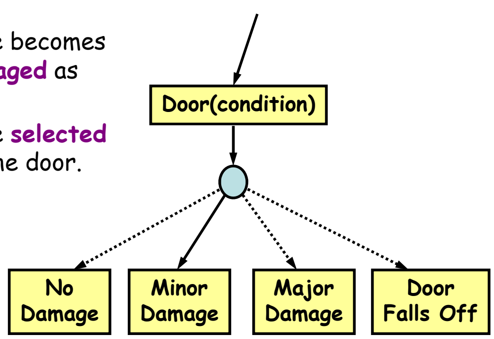
Model Switching:

We select among **multiple model instantiations** of a single entity by storing multiple child nodes and drawing only one, depending on the entity's **current state**.

Example:

A car door in a racing game becomes progressively more **damaged** as collisions occur.

Different door objects are **selected** based on the **state** of the door.



Chapter 3, Slide 20

Summary

Topics Covered:

- Basic elements of game design
- Game Architecture – basic structural elements and relations
- Sample game program structure and timing
- Scene graphs