Lecture 11

Networking
CS 3152: Game Networking Issues

**Consistency**
- Do our games agree?
  - Where do I see objects?
  - Where do you see them?
  - Who is authoritative?
- How to force agreement?
  - Do I wait for everyone?
  - Do I guess and fix errors?

**Security**
- What cheats are possible?
  - View hidden data
  - Enter invalid states
  - Improve player skill
- How do we cheat proof?
  - Technical solutions?
  - Community policing?
Consistency

- Do our games agree?
  - Where do I see objects?
  - Where do you see them?

- How to force agreement?
  - Do I wait for everyone?
  - Do I guess and fix errors?

Today’s Lecture

Security

- What cheats are possible?
  - View hidden data
  - Enter invalid...

- How do we cheat proof?
  - Technical solutions?
  - Community policing?

Not going to cover
The Issue of Consistency

- **Latency** is root of all evil
  - **Local** actions are instant
  - **Network** actions are slow

- **Example**: targeting
  - Want “geometric fidelity”
  - Fire a weapon along ray
  - Hits first object on ray
  - But movement is fast!

How to tell these cases apart?
World State vs. Local State

- **State**: all objects in game
  - **Local State**: on a machine
  - **World State**: “true” state

- **Where** is the world state?
  - On a single machine?
  - Union of local states?

- States may be **inconsistent**
  - Local disagrees with world
  - Is this really a problem?
  - What can we do about it?

![Diagram showing World State and Local State with overlapping circles](image)
The Question of Authority

Centralized Authority

- One computer is authority
  - Stores the full world state
  - Local states must match it
- Often call this the “server”

Distributed Authority

- Authority is divided up
  - Each object has an owner
  - Must match if not owner
- Classically call this “P2P”
Authority and Latency

- Lack of authority enforces a delay
  - Only draw what authority tells you
  - Requires round trip from your input
  - Round-trip time (RTT) can be > 200 ms

- This makes the game less responsive
  - Need some way to compensate for this

Sample Input
Render Screen

Client
- Sample Input
- Render Screen

Authority
- Process Input
- Compute State

Networking
Lack of authority enforces a delay
- Only draw what authority tells you
- Requires round trip from your input
- Round-trip time (RTT) can be > 200 ms

This makes the game less responsive
- Need some way to compensate for this

Need to understand basics before solving this
Networking Breaks into Two Phases

**Matchmaking**

- Service to find other players
  - Groups players in a session
  - But does not run session
- Why make your own?
  - Control user accounts
  - Implement skill ladders
- 3rd party services common
  - Apple GameCenter
  - GooglePlay API
  - Unity’s server classes

**Game Session**

- Service to run the core game
  - Synchronizes player state
  - Supports minor adds/drops
- Why make your own?
  - Must tailor to your game
  - You often have no choice
- Limited 3rd party services
  - Often just a networking API
  - For limited class of games
  - **Examples**: Unity, Unreal
# Networking Breaks into Two Phases

## Matchmaking
- Service to find other players
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- Why make your own?
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  - Apple GameCenter
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**Simplify if possible**

## Game Session
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  - **Examples**: Unity, Unreal

**Our main focus**
Matchmaking: Apple/iOS

- Uses the **GameKit** library
  - Supports multiplayer games
  - Also leaderboards/achievements
  - Not a full game engine

- Very simple matchmaking
  - Specify the number of players
  - Invite anyone on friends list
  - Invite anyone in BlueTooth range
  - Or allow Apple to hook you up

- Can be simultaneous with session
  - Add more players if slots available
# iOS Matchmaking Classes

## Real Time
- You handle authority
  - Allows variety of strategies
  - Focus of rest of lecture
- **GKMatchmakerViewController**
  - Classic matchmaking UI
  - You add a listener/delegate
- **GKMatchmaker**
  - Controller with no UI
  - Allows a custom view

## Turn Based
- Apple handles authority
  - Stores state on Apple server
- **GKTurnBasedMatchmakerViewController**
  - Classic matchmaking UI
  - You add a listener/delegate
- **GKTurnBasedMatch**
  - Controller with no UI
  - Allows a custom view
## iOS Matchmaking Classes

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**Will require you to use Objective-C++**
Advantages of a Custom UI

Networking

Key if mixing AI and multiplayer
Matchmaking: Android

- Part of the Google Play API
  - Supports multiplayer games
  - Also leaderboards/achievements
  - Also some minor game analytics
- Works exactly like GameKit
  - Choose real-time or turn-based
  - Use Google UI or a custom one
  - Only differ in terminology
- Has a native C++ API
  - No need for Java or JNI
  - See reading for documentation

Networking
Custom Matchmaking

• Typically need to have a separate server
  • Fixed, hard-coded IP that your app connects to
  • Custom user accounts that you manage
  • How Unity works (though they give software)

• **AdHoc Servers**: The cheap but ugly solution
  • One app declares itself to be a server
  • Other apps type in the IP address of that app

• **Benefit**: cross-platform matchmaking
  • Only way for iOS to play with Android
Custom Matchmaking

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This is allowed, but not if you are going to release on store.
Game Session: Part of Core Loop

- **Client**
  - Update
  - Draw

- **Authority**
  - Update

Networking
Decoupling the Network Loop
Decoupling the Network Loop

Client
- Local Update
- Draw
- Smooth local animation
- Possibly slower tick rate (10 fps)

Authority
- Update
- Should match the client rate

Networking
Decoupling Enables Latency Masking

- Animation is “buying time”
  - Looks fast and responsive
  - But no real change to state
  - Animation done at update

- **Examples:**
  - Players wait for elevator
  - Teleportation takes time
  - Many hits needed per kill
  - Bullets have flying time
  - Inertia limits movement

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**Network Options**

Setting lower latency reduces the time between when you click the mouse and when a unit responds to the click.

Higher latency increases that time, but smooths network performance for systems with slow or 'lossy' network connections.

- Low latency
- High latency
- Extra high latency

[OK] [Cancel]
Game Session: Dedicated Server

- Server developer provides
  - Acts as central authority
  - May be several servers
  - May use cloud services

- Pros:
  - Could be real computer
  - More power/responsiveness
  - No player has advantage

- Cons:
  - Lag if players not nearby
  - Expensive to maintain
Game Session: AdHoc Server

- One client acts as host
  - Acts as central authority
  - Chosen by matchmaker
  - But may change in session

- **Pros:**
  - Cheap long-term solution
  - Can group clients spatially

- **Cons:**
  - Server is a mobile device
  - Host often has advantages
  - Must migrate if host is lost
Game Session: AdHoc Server

- One client acts as host
  - Acts as central authority
  - Chosen by matchmaker
  - But may change in session

- Pros:
  - Predominant commercial architecture

- Cons:
  - Server is a mobile device
  - Host often has advantages
  - Must migrate if host is lost
Game Session: True P2P

- Authority is distributed
  - Each client owns part of state
  - Special algorithms for conflict
  - Coordinator for adds/drops

- Pros:
  - No lag on owned objects
  - Lag limited to “attacks”
  - Same advantages as adhoc

- Cons:
  - Incredibly hard to implement
  - High networking bandwidth
Game Session: True P2P

- Authority is distributed
  - Each client owns part of state
  - Special algorithms for conflict
  - Coordinator for adds/drops

- Pros:
  - Almost no-one does this outside academia
  - Participating in globally adhoc

- Cons:
  - Incredibly hard to implement
  - High networking bandwidth
Game Session: True P2P

Networking
Game Session: True P2P

Melee is easy to latency mask!
Clients must be *synchronized*
- Ensure they have same state
- … or differences do not matter

Synchronization != authority
- Authority determines true state
- Not *how* clients updated
- Or *when* clients are updated

Major concept in networking
- Lots of complicated algorithms
- Also a *patent* *mindfield*
- Take distributed systems course
### Synchronization Algorithms

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Pessimistic: Lock-Step Synchronization

- **Algorithm**: play by “turns”
  - Players send turn actions
  - Even if no action was taken
  - Wait for response to render

- **Problems**
  - *Long* Internet latency
  - Variable latencies (jitter)
  - Speed set by slowest player
  - What if moves are lost?

- More common in LAN days
Pessimistic: Bucket Synchronization

- **Algorithm**: turns w/ timeout
  - Often timeout after 200 ms
  - But can be adapted to RTT
  - All moves are buffered
  - Executed at end of *next* turn

- **Problems**
  - Variable latencies (> a turn)
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- Used in classic RTS games
**Pessimistic: Bucket Synchronization**

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Optimistic: Personal State

Current Network State

Unconfirmed player actions

Approx. Current State

Previous Network State

State updates

Player action confirmations

Current Network State

Networking

True State

Local Update

Draw

Network Update

Server Update
Optimistic: Opponent State

- **Local Update**
  - **Draw**

- **Network Update**

- **Server Update**

- **Current Network State**
  - Simulate assuming no actions

- **Previous Network State**
  - State updates

- **Approx. Current State**
  - Current Network State

- **True State**
  - Opponent actions
Advantages of Sending Actions

**Dead Reckoning**
- Assume velocity constant
  - Simulate the new position
  - Treats like physics object
- Generalize to other actions

**Error Smoothing**
- Can interpolate late actions
  - Create simulation for action
  - Avg into original simulation
- Continue until converge

Networking
The Perils of Error Correction
Physics: Challenge of Synchronization

- Deterministic bi-simulation is very hard
  - Physics engines have randomness (not Box2D)
  - Not all architectures treat floats the same

- Need to mix interpolation with snapshots
  - Like error correction in optimistic concern
  - Run simulation forward from snapshots
Physics: Challenge of Synchronization

- Deterministic bi-simulation is very hard
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- Need to mix interpolation with snapshots
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  - Run simulation forward from snapshots
Physics: Challenge of Authority

• Distributed authority is very difficult
  • Authority naturally maps to player actions
  • Physics is a set of interactions

• Who owns an uncontrolled physics object?
  • **Gaffer**: The client that set in motion
  • Collisions act as a form of “authority tag”
Summary

- **Consistency**: local state agrees with world state
  - Caused by latency; takes time for action to be sent
  - Requires complex solutions since must draw now!

- **Authority** is how we measure world state
  - Almost all games use a centralized authority
  - Distributed authority is beyond scope of this class

- **Synchronization** is how we ensure consistency
  - Pessimistic synchronization adds a sizeable input delay
  - Optimistic synchronization requires a lot of overhead