Console Architecture

Overview

- What is a console?
- Console components
- Differences between consoles and PCs
- Benefits of console development
- The development environment
- Console game design
- PS3 in detail
- Console transitions

What is a Console?

- Consoles are dedicated game machines

- The active platforms
  - Nintendo Switch, WiiU, Wii, GameCube, Nintendo64
  - Microsoft Xbox Series X, Series S, Xbox One X, Xbox One, Xbox 360, Xbox
  - Sony Playstation 5 (PS5), PS4, PS3, PS2, Playstation (PSX)

- Interesting lineages that have died out
  - Nintendo DS / 3DS (Mostly dead)
  - Playstation Portable (PSP), Vita
  - Dreamcast, Saturn
  - 2D consoles like the NES and SNES
  - Failed attempts like Ouya

Console Benefits

- Fixed target
  - Makes it easier to eke out performance
  - More exposure of underlying hardware
- Consoles are dedicated to games
  - Dedicated hardware, dedicated software platform (e.g. trophies, matchmaking), dedicated sales channels
- Bigger market
  - Consoles are cheaper
  - More accessible
  - More people have them
    - PC hardware market is bigger, but a lot of that is for businesses
  - Consoles are more secure
    - Arr matey, there be less copyright infringement!
  - More people buy games
  - More $$$ for developers

Console Liabilities

- Underpowered
    - Particularly near the end of it's life
- No keyboard, mouse
    - Makes control systems for FPS and RTS games difficult
    - Some modern consoles have capability to use them, but can't generally depend on them
- Less open production / distribution models

The Development Environment

- Games are written on a host machine
  - PC
  - Mac
  - Linux

- Compiled on the host with a cross-compiler
  - Visual Studio for Xbox
  - LLVM/Clang For Playstation and Switch

- Downloaded to development system through a network (or USB or other wired connection on older hardware)

Development Hardware

- Manufacturers generally loan/rent/sell hardware specifically for developers
- Generally has some capabilities that the retail hardware doesn't
  - Ability to run unsigned binaries
  - More memory
  - Debug monitor hardware or software to communicate with host
  - More complicated custom functionality
    - DVD Emulator on Xbox 360
- Retail Xbox One units can also be used for development
- The game runs on the development system.
- Debugging is done remotely over network

Development Libraries

- Used to be very seat of the pants (little OS support, buggy libraries)
- Quality has been upped in last couple of generations
  - Largely driven by Microsoft
- Lots of variation between consoles
- Support can be weak
  - Particularly early in lifecycle
  - Libraries coming in late
  - Poor documentation
  - Bugs

Game Design

- Console architecture can have an effect on game design
- Different input mechanisms
  - Can only depend on gamepad
- Console games are played in a different environment
  - Living room, TV, stereo
  - Party gaming
- Console gamers represent a different market
  - Some markets still live on PC (MMO, Strategy)
  - Nintendo consoles have a much broader base of players

Distribution Control

- Manufacturers control access to the distribution channels
  - Need to be in a partnership with them to ship a game
  - They take a share of the money from all sales
- Various requirements that must be met to be allowed to publish even once agreement is in place
  - May limit allowed content is some ways (i.e. no porn games)
  - Manufacturer performs some QA and title to make sure it is stable
  - Various specific behavioural requirements might need to be met
    - Show screens in particular ways (i.e. autosave warning)
    - Interact with standardized technology in certain ways (save games, voice chat)
    - Meet certain behaviour requirements (Have trophies, support progressive downloads)

Console Evolution

- Playstation (1995)
  - 33 MHz MIPS R3000 derivative, 2 MB RAM, CD (600MB)
- Playstation 2 (2000)
  - 300 MHz MIPS R5000 derivative, 32 MB RAM, DVD (9 GB)
- Playstation 3 (2006)
  - 3 GHz Cell (8 cores), 512MB (split) RAM / Blu-ray (50 GB)
  - 32 shader cores @ 550 MHz
- Playstation 4 (2013)
  - 1.6 GHz 8-core x64 CPU, 8 GB, Blu-ray / Hard drive
  - 1152 shader cores @ 800 MHz
- Playstation 4 Pro (2016)
  - 2.1ghz 8-core x64, 8 GB, Blu-ray / Hard drive
  - 2304 shader cores @ 911 MHz
- Playstation 5 (2020)
  - 3.5ghz 8-core x64, 16 GB, Blu-ray / SSD
  - 2304 shader cores @ 2233 MHz

A Third Generation 3D Console

- Released in 2006
- 3.2 GHz CPU
- 8 CPU cores
- 2 × 256 MB RAM
- Blu-ray
- Up to 320 GB HDD
- Gigabit Ethernet
- WiFi
- Bluetooth
- USB

CPU

- 1 Power Processing Element (PPE)
  - PowerPC instruction set
  - 2 × 32k L1 caches
  - 512k L2 cache
  - 64 and 128 bit register sets
  - 2 hardware threads
- 7 Synergistic Processing Elements (SPE)
  - Custom instruction set
  - 256k embedded SRAM
  - 128 × 128 bit SIMD registers
  - Main memory access via DMA only
- High throughput, high latency design trade-off

Graphics

- Half the main memory is VRAM
  - Fast to read by GPU (22 GB/s)
  - Fast to write by CPU (4 GB/s)
  - Slow to read by CPU (16 MB/s)!
- RSX graphics chip
  - 550 MHz
  - Based on NV47 (GeForce 7800)
  - Parallel programmable shader pipelines
    - 8 vertex
    - 24 pixel
  - 24 texture filtering (TF) units
  - 8 texture addressing (TA) units
  - Peak theoretical pixel fill rate 4.4 Gpixel/s

Development Environment

- Compilers
  - GCC version provided by Sony
  - SNC provided by SN Systems (Sony's subsidiary)
- IDEs
  - Visual Studio integration plugin from SN Systems
- Debuggers
  - ProDG Debugger from SN System
- Graphics libraries
  - GCM
  - PSGL

PlayStation 3 Issues

- Memory dichotomy
  - All budgets need to be expressed in two values
  - CPU memory is premium

- Heterogeneous CPU architecture
  - Different compile/link/execute path for SPUs
  - Lack of direct addressing
  - Learning threshold for programmers
    - Big performance gains once you get over it

- RSX performance
  - Addition of RSX was an afterthought
  - Rendering is a bottleneck
  - Can/must be circumvented by better use of SPUs
    - But then the advantage of having the SPUs is less

The 4th Generation 3D Consoles

- PS4 and Xbox One Have remarkably similar architectures
  - Also very similar to PCs
- Very straightforward
  - Intel x64
  - 8 homogenous cores
  - Unified memory (mostly)
  - Fast GPUs (~800mhz, ~1000 shader units)
- PS4 fixes almost all of the issues with the PS3
  - Xbox 360 had way less issues
- Hard drive only (sort of)
- Similar enough that supporting both has become even easier
- 5th gen is more of the same

Console Transitions

- Because console are fixed targets, eventually they get out of date

- Refreshes generally happen to all ecosystems at once
  - Nobody wants to be (too far) behind
    - Except Nintendo

- Lots of business turmoil during a transition
  - Sega messed up the Saturn in the first gen and the Dreamcast wasn't enough to save them so they exited the hardware market
  - PS2 absolutely dominated, but Sony lost their lead in the PS3/360/Wii generation.
  - Wii U was a catastrophe, many people though Nintendo might be out of hardware if the Switch didn't take off.

Last Console Transition

- Last full transition
  - Started November 2012 (Wii U)
  - Sony and Microsoft shipped hardware (PS4 / Xbox One) in 2013

- From a development perspective, the last transition was as easy as you could hope for
  - No strange new architectures
  - No new programming models
    - Compute Shaders are more usable than previous consoles
  - More performance, and more predictable performance
  - Lots more memory

Last (Partial) Transition

- Unusual mid generation update
  - Started October 2016 with launch of PS4 Pro
  - Xbox One X and Switch in 2017

- This transition was pretty weird
  - Nintendo doing a full transition several years earlier than expected due to failure of Wii U
    - Switch was VERY successful, still underpowered though
  - Sony and Microsoft revving hardware but maintaining full backwards AND forwards capability, a lot like buying a new video card
  - Cycle was shorter than a console transition ever has been before, but might be longer if you count to the end of the PS4 Pro / Xbox One X's life

Current Transition

- PS5 and Xbox X Series XS 2 Championship Edition (or whatever)
  - Evolution of current architectures (X86, AMD GPU), just beefed up
  - SSD installs
  - Backwards compatibility
  - Digital only SKUs
  - MS Pushing into streaming gaming
  - Another terrible name from Microsoft

- Still some unknowns
  - VR?
  - Nintendo?

In Closing

- Consoles present many interesting challenges.

- The fixed platform that consoles offer is both advantageous and limiting.

- The future is always in motion