# **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
  - Nintendo WiiU, Wii
  - Nintendo GameCube (NGC)
  - Nintendo64 (N64)
  - Nintendo DS / 3DS
  - Nintendo GameBoy Advanced (GBA)
  - Xbox One, Xbox 360, Xbox
  - Sony Playstation 4 (PS4), PS3, PS2, Playstation (PSX)
  - Playstation Portable (PSP)
  - Playstation Vita
  - Sega Dreamcast (DC)

# **Console Evolution**

- Sony Playstation (1995)
  - 33 MHz MIPS R3000 derivative
  - 2 MB RAM
  - CD-based storage (~650 MB / disc)
- Sony Playstation 2 (2000)
  - 300 MHz MIPS R5000 derivative
  - 32 MB RAM
  - DVD-based storage (~9 GB / disc)
- Sony Playstation 3 (2006)
  - 3 GHz Cell processor (PowerPC core plus 7 custom SPUs)
  - 256 MB CPU RAM plus 256 MB Video RAM
  - Blu-ray-based storage (50 GB / disc)
- Sony Playstation 4 (2013)
  - 1.6 GHz 8-core x64 CPU
  - 8 GB Unified GDDR RAM
  - Blu-ray + 500GB HD

# Differences from PC

- Output to TV rather than monitor
  - Lower resolution
  - Poor colour reproduction on older generations (NTSC)
- Limited permanent storage until this generation
  - No hard disk on Xbox and Wii
  - No virtual memory
    - Can implement it yourself on PS3 though
  - Slow physical media access
    - As compared to HD access
- 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

# **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)
- 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
    - Less copyright infringement
  - More people buy games
  - More \$\$\$ for developers

# **Console Liabilities**

- Underpowered
  - Particularly near the end of it's life
- Little, or no operating system
  - DIY memory management
  - Lots of hardware level programming
    - Interrupt handlers
    - DMA
    - Task scheduling
    - Assembly
- 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
  - GCC and SN compilers for PS3
  - CodeWarrior for Nintendo Wii
- Downloaded to development system through a network or USB connection

# Testing and Debugging

- The game runs on the development system.
- Debugging is done remotely
  - Can be across regular network connection (Xbox, PS3)
    - Integrated seamlessly into Visual Studio for Xbox
    - Separate app (SN Debugger) for PS3
  - Or custom connection (GameCube, all earlier consoles)
- Rather than burning disks, a DVD emulator is used to allow games to test streaming systems, etc.

## **Development Libraries**

- There is little in the way of an operating system, but there are usually some libraries to help you get off the ground
- 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 a large effect on game design:
  - Limited memory:
    - Reduce size of world or stream from DVD
  - Lower resolution
- Different input mechanisms
  - Can only depend on gamepad, that affects design
  - Motion control getting pretty ubiquitous
- 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)
  - Wii has a much broader base of players

# 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

#### **Console transitions**



# **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 (to far) behind
- Last transition
  - Started November 2005 (XBox 360)
  - Took roughly a year for all hardware to refresh
  - Some things lingered
    - Software takes a while to taper off
    - PS2 still manufactured till last year
- Current transition
  - Started November 2012 (Wii U)
  - Sony and Microsoft shipped new hardware in 2013
  - Hardware may have longer post replacement shelf life this time

## **Console transitions**

- Lots of business turmoil during a transition
  - Last one started with Sony in a dominant position and Microsoft and Nintendo as also-rans
  - Finished with Nintendo out in front (but not as far as Sony had been), and MS narrowly beating Sony
    - Though split by territory was pretty dramatic
  - Could someone get 'Dreamcasted'?
- New platforms open up new possibilities
  - Last generation brought us motion controls
  - Nintendo is banking on multi-screen gaming this time out
  - Better hardware enables various enhancements
  - Means learning a bunch of new stuff

### The next Sony and Microsoft consoles

- PS4 and XBox One shipped for Christmas 2013
- Predictable improvements in overall performance
- Architecturally very similar to a PC
  - Very little special games hardware
    - Mostly controller improvements
    - Some custom silicon on CPU/GPU
  - Significant improvements to software platform
    - Video Streaming, Play while installing, etc.
- Microsoft tried to switch to full digital distribution of games, but backed out due to customer complaints

## Console transition

- From a development perspective, this 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
- It's less clear how the transition will work out from a business perspective, or who will "win" this generation

# In Closing

- Consoles present many interesting challenges.
- The fixed platform that consoles offer is both advantageous and limiting.
- Consoles are entering a very turbulent year or two.