How Valve Makes Games Better with Xperf

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Introduction

• Xperf is awesome (see last year’s Gamefest talk)
• Xperf has a “challenging” learning curve

• Talk goals:
  • Pass on the Xperf lessons learned at Valve
  • Pass on the techniques Valve uses (including sample code)
  • Encourage a common perf-interchange format
  • Force me to learn ETW/Xperf more thoroughly
What is Xperf?

- Free, whole system ETW profiling tool
  - ETW stands for Event Tracing for Windows
  - Disk, CPU, GPU, processes, threads, etc.
- Includes sampling profiler
- Used extensively by Microsoft
- Profiling without Xperf is also known as “guessing”
  - “I think our level loads are bound by I/O time” (there was none)
  - “I think our level loads are bound by CPU time” (wrong again)
Stuff Xperf Found

- 400 ms startup hang on Portal 2 and Dota 2
- 10 s of static lighting initialization on map load
  - On a game that didn’t use static lighting
- 3 s of wasted time during map load
- 100,000 unintentional memory allocations
- Conditional breakpoint accidentally left enabled
- Excessive assert cost in debug builds
- Many, many, more
How Valve Uses Xperf

• You can record just system data
  • Sampling profiler, Disk I/O, page faults, context switches, DirectX information, memory allocations, etc.
• But, system data is much more valuable with context:
  • Frame start/frame rate
  • Key events (begin/end task, etc.)
  • Network traffic
  • User input
  • Etc.
• User providers let you provide this context
Some things Valve’s user providers tell us include:

- User input
- Frame boundaries
- Network traffic

Rows of diamonds represent:

- Server frame rate
- Client frame rate
- Network events
- Start/stop events and markers
- User input

- One line per provider
Common Timeline

- The real power is when user events are in the same view as system events.

  - Idle CPU
  - Server process CPU time
  - Map load request
  - Minimal disk I/O (all writes)
Digging Deeper: Summary Tables

- Grouping is powerful
- Time is recorded for all events
- Input events are awesome

<table>
<thead>
<tr>
<th>Line</th>
<th>Path Name</th>
<th>Process Name</th>
<th>Service Time (us)</th>
<th>Size</th>
<th>Write Size</th>
<th>Flush Count</th>
</tr>
</thead>
<tbody>
<tr>
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<td>System</td>
<td>256,242,178</td>
<td>0</td>
<td>0</td>
<td>6</td>
</tr>
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<td>0</td>
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</tr>
<tr>
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</tr>
<tr>
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<td>65,536</td>
<td>65,536</td>
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</tr>
</tbody>
</table>

80 wpm
How Valve Uses Xperf

- Tracing is always on
- Kernel data goes to a 600 MB circular buffer
  - ~2 minutes of data on a busy 12-proc machine
- User data goes to a 100 MB circular buffer
  - ~2-100 minutes of data depending on what providers are active
- Buffers can be saved to disk after a performance problem is noticed
  - Retroactive profiling

In-memory circular buffers
Demo

- Load various Xperf traces and show actual issues found at Valve
Xperf Compared to Bracketed Event Profilers

- PIXBegin/EndNamedEvent style profilers coexist well with xperf
- Bracketed Event Profilers:
  - Have lower data rate, for faster data manipulation
  - Make slow frames easier to see
- Xperf:
  - Shows OS details (other processes, disk, locks, etc.)
  - Shows what happens between the bracketed events
  - Works when there are no events
ETW User Provider Definition (Manifest File)

**Provider definition**
- Name, location, and GUID
- Can have one or more event payloads. Available types include:
  - Signed/unsigned 8-bit, 16-bit, 32-bit, and 64-bit integers
  - ANSI and Unicode strings
  - Float and Double
  - Boolean, Binary, GUID, Pointer, FILETIME, SYSTEMTIME, SID, SLIDE

**Static event data**
- Used to aid in interpreting, sorting, and grouping

**Event definitions**
- Ties together payload and static data
- Your code emits events

```xml
<provider
guid="(2B25961D-BA6E-4D79-BEC7-36053666E209)"
name="Multi-FrameRate"
symbol="MULTI_FRAMERATE"
messageFileName="%temp%\MultiProvider.exe"
resourceFileName="%temp%\MultiProvider.exe"
/>

<templates>
<template tid="T_FrameMark">
<template id="T_FrameMark">
<data inType="winInt32" name="Frame number" />
<data inType="winFloat" name="Duration (ms)" />
</template>
</templates>

<opcodes>
<opcode name="FrameMark" symbol="_FrameMarkOpcode" value="10"/>
</opcodes>

<tasks>
<task name="Frame" symbol="Frame_Task" value="1"
  eventGUID="{43DADA85-4986-4438-83D6-931477635DE3}"/>
</tasks>

<events>
<event symbol="FrameMark" template="T_FrameMark" value="200" task="Frame" opcode="FrameMark"/>
</events>
</provider>
Writing an Instrumentation Manifest


You can use Visual Studio:
- Get `\Include\Eventman.xsd` XML->Schemas menu to input data

You can use Manifest_Generator (ECManGen.exe) to edit inst:
- From the Platform SDK

You can go old school:
- Notepad!
Compile Manifest

- `mc.exe -um %(Filename)%(Extension) -z %(Filename)Generated`
- Generates:
  - %(Filename)Generated.h
  - %(Filename)Generated.rc
  - %(Filename)Generated.MSG00001.bin (compiled into resource file)
  - %(Filename)GeneratedTEMP.bin (compiled into resource file)

- Don’t check in the generated files
- Don’t forget to build the resource file into your program
Valve’s ETW API

#ifdef WIN32
PLATFORM_INTERFACE int64 ETWMark( const char *pMessage );
PLATFORM_INTERFACE int64 ETWMarkPrintf( const char *pMessage, ... );

PLATFORM_INTERFACE int64 ETWBegin( const char *pMessage );

PLATFORM_INTERFACE int64 ETWEnd( const char *pMessage, int64 nStartTime );

PLATFORM_INTERFACE void ETWRenderFrameMark();
PLATFORM_INTERFACE void ETWSimFrameMark();

PLATFORM_INTERFACE void ETWMouseDown( int nWhichButton, int nX, int nY );
PLATFORM_INTERFACE void ETWMouseUp( int nWhichButton, int nX, int nY );
PLATFORM_INTERFACE void ETWKeyDown( int nScanCode, int nVirtualCode, const char *pChar );

PLATFORM_INTERFACE void ETWSendPacket( const char *pTo, int nWireSize, int nOutSequenceNR, int nOutSequenceNrAck );
PLATFORM_INTERFACE void ETWThrottled();
PLATFORM_INTERFACE void ETWReadPacket( const char *pFrom, int nWireSize, int nInSequenceNR, int nOutSequenceNRAck );
#else
// Inline NOP functions for cross-platform compatibility
#endif
Valve’s ETW API Implementation

• Startup/shutdown:

```
#include <ETWProviderGenerated.h>
EventRegisterValve_Network(); // Call this at process startup for each provider
EventUnregisterValve_Network(); // Call this at process shutdown for each provider
```

• Implementation

```
void ETWSendPacket( const char *pTo, int nWireSize, int nOutSequenceNR, int nOutSequenceNrAck )
{
    static int s_nCumulativeWireSize;
    s_nCumulativeWireSize += nWireSize;
    // EventWriteSendPacket is a macro in the generated header file
    EventWriteSendPacket( pTo, nWireSize, nOutSequenceNR, nOutSequenceNrAck, s_nCumulativeWireSize );
}
```

• XP compatibility thunks:

```
#define EVNTPAPI__stdcall
#include "ETWProviderGenerated.h"
ULONG EVNTPAPI EventWrite( REGHANDLE RegHandle, PCEVENT_DESCRIPTOR EventDescriptor, ULONG UserDataCount, PEVENT_DATA_DESCRIPTOR UserData )
{
    if ( g_ETWRegister.m_pEventWrite )
        return g_ETWRegister.m_pEventWrite( RegHandle, EventDescriptor, UserDataCount, UserData );
    return 0;
}
```
Demo

- Run Visual Studio, load the sample, and build it
- Register the providers
  - `xcopy /y yourgame.exe %temp%
  - `wevtutil um etwmanifest.man`  
  - `wevtutil im etwmanifest.man`
- Run the sample
- Record a trace, analyze it
  - `Etwrecord.bat myfirsttrace.etl`
Necessary Sample Customizations

- Replace all GUIDs in ETWProvider.man to avoid conflicts
- Rename provide ‘name’ and ‘symbol’ in ETWProvider.man
  - Also update etwcommonsettings.bat and etwprof.cpp to match new names/symbols
- Adjust ‘messageFileName’ and ‘ResourceFileName’ in etwprovider.man, and DLLFileMain and DLLFileAlternate in etwregister.bat
Technical Challenges

- 32-bit stack walking is buggy on 64-bit Windows Vista
  - Sampling profiler becomes useless
  - Luckily we use 64-bit Windows 7
- Xperf/ETW work on Windows XP (with many limitations), but won’t install on Windows XP
  - Find 32-bit Windows Vista or Windows 7 machine, install there. Copy the install image
- Running applications off of non-system drive is busted
  - Use mklink/junction to hack around this
    - mklink /j c:\dota d:\dota
- No easy way to record traces on customer machines
  - Working on an installer and Xperf wrapper
Process Simplifications

- Installation from Windows SDK is tedious
  - Make local distribution directory for xcopy install
- Syntax for recording tracing is byzantine
  - Make bullet proof batch files, put in distribution directory
- xcopy install is too much work (???)
  - Allow running batch file from network drive
- Typing batch file parameters is hard
  - Make all parameters optional
- Users might not register or have user providers
  - Make batch files fallback gracefully if providers aren’t registered
More Process Simplifications

- 64-bit stack walking requires setting reg key, rebooting
  - Set reg-key in batch files
  - Get IT to deploy the reg key using group policy
- Frame Pointer Omission (/Oy) breaks 32-bit stack walks
  - Change all project files to /Oy-, default with VS 2010
- Developers won’t run circular buffer recording
  - Automatically start/stop it when recording traces
- Creating junctions is annoying
  - Modify batch files to do it automatically
- Not everyone has _NT_SYMBOL_PATH set
  - Have batch files set it if not already set
Ultimate Simplification

- Redistributable Xperf wrapper is possible
- About three days work
- Installs xperf
- Buttons for starting and stopping circular buffer tracing, recording traces
- Also registers providers
- Adds global hot key for recording traces

![Record Valve Perf Trace window](image)
If this keeps showing up, then create a symsrv.yes file in the Xperf install directory.

81% of CPU time in this region is in code I don’t have symbols for.

Microsoft Internet Symbol Store

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Yes  No

Gamefest 2011
Xperf as Perf-interchange Format

• No company is an island
  • Valve uses projects and source from other companies
  • Valve uses DLLs from other companies
  • We need them built with /Oy- and symbols so we can profile our game with this foreign code inside it
• When we hit problems in your code, we want to send you an ETW file
• If you hit problems in our code, we want you to send us an ETW file
• Common toolset allows sharing techniques and skills
• Common toolset allows reporting perf-bugs in others’ code
Xperf for Other People’s Software

- Recording graphics performance problems, sending traces to IHVs
- Found and reported opportunities for improved performance in PowerPoint, Visual Studio, and Windows Live Photo Gallery
- Used Xperf to profile third-party profiler, and itself
- Server performance problem due to Windows bug
- Profiling Valve’s games before starting at Valve
- Poor network perf caused by network driver DPC time
Platform SDK

- Make sure you are getting the latest version
- Contains Xperf, and Xperf installers
- Also contains Manifest_Generator, GUID Generator, eventman.xsd
  - Plus other goodies like Application Verifier, debuggers, etc.
- Note that with Visual Studio 2010 SP1 installed, the Platform SDK will fail to fully install
  - To avoid this failure, don’t install the SDK compilers
  - If they’re needed, you can install them afterward from [http://go.microsoft.com/fwlink/?LinkId=212355](http://go.microsoft.com/fwlink/?LinkId=212355)
Corrections

• The undocumented “-capturestate” option to xperf does not work on Vista
  • Sorry – you’ll have to fix the batch files
  • But tracing works better on Windows 7 anyway
  • And it’s not documented
Other Xperf Stuff I’d Cover if I Had Time

- Heap profiling
- GPUView
- Finding UI hangs
- Advanced threading analysis
- Summary tables, summary tables, summary tables
- Python script for packaging up .symcache files used by a trace
Resources

  - Resource links, slides, and sample project are here. Future updates will go here
- See sample code
  - Uses multiple ETW providers to record game-relevant data
  - Includes batch files for recording traces
  - Readme.txt explains what to do
- Last year’s xperf talk
- Platform SDK
- Writing an instrumentation manifest
- Documentation of all event payload template types
  - [http://www.bing.com/search?q=xperfview](http://www.bing.com/search?q=xperfview)