Keys to Successful IA-64 Software Development

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Agenda:
Key IA-64 Software Issues

- Do I Need IA-64?
- Coding for Portability
- Coding for Performance and Maintainability
- Mixing IA-32 and IA-64
- Planning for an Optimal Product

Need IA-64 Yet?

- Want More Performance?
  - IA-64 removes performance bottlenecks
  - IA-64 is a parallel/scalable architecture
- Need More Than 2 or 3 Gigabytes?
  - Technology exponential (feeds on itself)
  - Data space growing at ~.7 bits/yr
  - Hard to anticipate market 5 years out

Start IA-64 Development Now

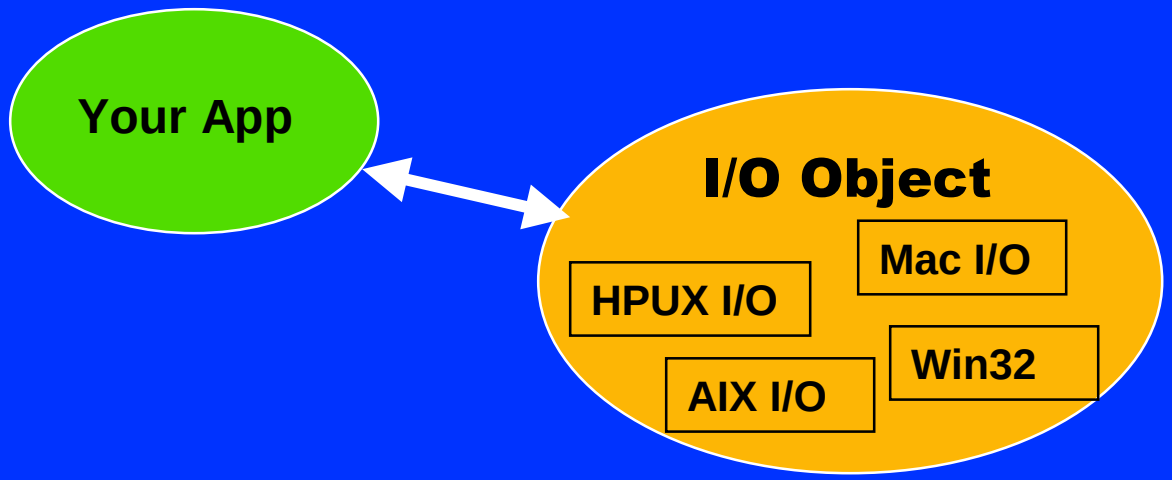
Coding for Portability

- Abstract the OS API
  - Extra layer to encapsulate OS calls
- Use a Unified Data Model
  - Polymorphic types to support 32 and 64 bit processors
- Minimize Processor Dependencies
  - Minimize Assembly (use intrinsics)

OS and Processor Independent Coding Is Easy

Old Hat: Abstract the OS' API

- If you support Unix and NT, you probably already do this
- C++ and OOP have taught us how
- Some APIs already standard: OpenGL



The New Challenge: Abstracting the Data Model

- Not harder, but perhaps new
- Single source for 32 and 64 bit processors very desirable:
  - Termed Unified Data Model (UDM)
- OS vendors have done it, now it's your turn

Terms to Know

- Code Clean
  - Revising source code to be compilable in ***both*** 64-bit *and* 32-bit environments.
- Polymorphic
  - One data item having a different type to different users/viewers. A key source of code-clean problems.
- "Data Bloat"
  - Increase in size of data in 64-bit applications.
- Cardinality
  - The range of numbers a data item can count.

Topics that could previously be ignored in the 32-bit world

Windows & UNIX Use Different Data Models

- **OS vendors tried hard to minimize changes**

  Windows chose P64, Unix chose LP64

OS	Data Model	`int`	`long`	pointer
UNIX/64	I32,LP64	**32**	64	**64**
Win64	IL32,P64	**32**	32	**64**

- **If using `long`, you must change it to maintain platform independence!**
  - Suggestion: Replace with new type defined in a <compatible.h> file.

See IDF Tracks: Porting to Monterey*/Linux* on IA-64

Use ANSI Types for Platform Independence

- ANSI* types with universal meaning on Unix, Win32, Win64:
  - New polymorphic integer: intptr_t
  - Old polymorphic cardinal type: size_t
  - Good old 32 bit integers: int
- Try to avoid OS dependent types:
  - INT_PTR, SIZE_T, (Windows only types)

*Reference: ANSI C99 Specification (ISO/IEC 9899:1999)

Code Cleaning Steps

- Switch to the Unified Data Model
  - use polymorphic types
- Perform required API tweaks
  - typically, small number of semantic changes (can be automated)
- Compile with code clean switch to catch problems
  - pointer truncations, etc. Not easily automated

Single Source Code for IA-64 / IA-32

See IDF Sessions: Porting to Win64*/Montery*/Linux* on IA-64

Use a Portability Header File

#include <portatyp.h>

- **Used by *all* your source files**
- **Write your source using these standard-inspired types**

```
/* portatyp.h */
#if defined(_WIN32)
… // stuff related to Win32
#if !defined(_WIN64)
… // Win32 without Win64 (regular Win32)
#else /* is _WIN64 also */
… // Win64 variant of Win32
#endif /* _WIN64 ? */
#elif defined(__unix) || …
… // various UNIXes
#else /* some other OS */
#error Unhandled OS;
#error   update <portatyp.h>!
#endif
```

Enhance Portability & Readability

Processor Dependencies

- Use significant architectural features for performance

... but

- Use pragmas, macros, and intrinsics to minimize platform dependencies
- Rely on the compiler as much as possible

Processor Dependencies (continued)

- SIMD instructions
  - Use intrinsics, encapsulate in a class
  - http://developer.intel.com/vtune/cbts/strmsimd/appnotes.htm
- Rely on the compiler for:
  - Loop unrolling
  - Vectorizing
  - Proper insertion of prefetch intrinsics

Coding for Performance and Maintainability

- Modular programming (using DLLs, classes, and small functions) promotes maintainability!

  … but it also

  - adds overhead and
  - limits what a compiler can do

- IA-64 promotes modular programming <u>without the performance loss!</u>

Special Support for Modular Programming

- **Hardware:**
  - Register Stack Engine (minimize stack frame save/restore)
  - lots of registers (schedule more operations)
- **Software:**
  - Interprocedural Compiler Optimizations (IPO):
    - let the compiler see more code
  - Profile Guided Compiler Optimizations (PGO):
    - drive IPO decisions with real performance data
  - High Level Optimizations (HLO):
    - loop unrolling, vectorization, prefetch, blocking

New Compiler Usage Model

- IA-64 offers more opportunity for compiler optimizations

IA-32 Model

Debug	Release
Od	Ox

IA-64 Model

Debug	Release
Od	Ox Oa HLO PGO IPO

Software Pipelining Is A BIG Performance Deal

- Dynamic memory (pointers) allows SW to support wide range of HW configurations!

  … but it also

  – limits the compiler's ability to software pipeline

- Disambiguate pointers with:
  - restrict keyword (loop level control, now in ANSI C)
  - #pragma optimize("a") (function level control)
  - No aliasing flag (Oa, file level control)

Help the Compiler Pipeline your Loops

Using restrict To Allow Software Pipelining

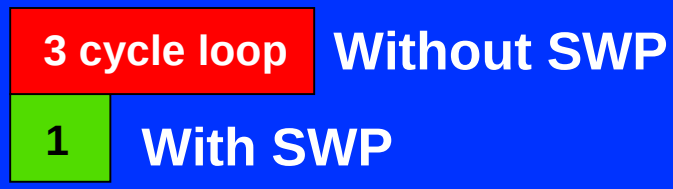
```
void VSquare
( double* restrict pX, double* restrict pY, int n )
{ for ( int i=0; i<n; i++ ) pX[ i ] = pY[ i ] * pY[ i ]; }
```

Use restrict when you know pX and pY point to distinct objects (i.e., do not overlap).

Software Pipelining (SWP)
some examples

- SSL Kernel Loop (3 cycle, 9 stage)

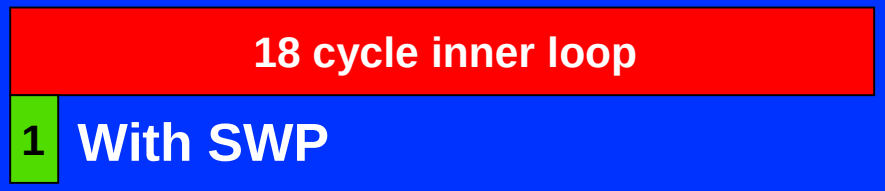
- MemCopy (1 cycle, 3 stage)



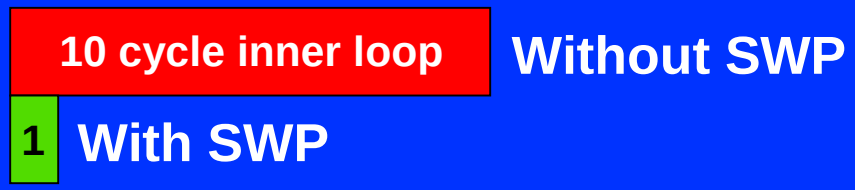
Compiler Can Do This For You

Software Pipelining (SWP)
some more examples

- Vector Scale (1 cycle, 18 stage)



- Dot Product (1 cycle, 10 stage)



Compiler Can Do This For You

Interprocedural Optimization – IPO

Compiler looks at entire program:

- Inlining, partial inlining
  - HW promotes greater benefits from
- Interprocedural constant propagation
- Circumvent legacy calling convention
- Enables data layout
  - better data alignment and d-cache hits
- Dead call, partial dead call removal

Profile Guided Optimization – PGO

Drive the compilation process with real performance data:

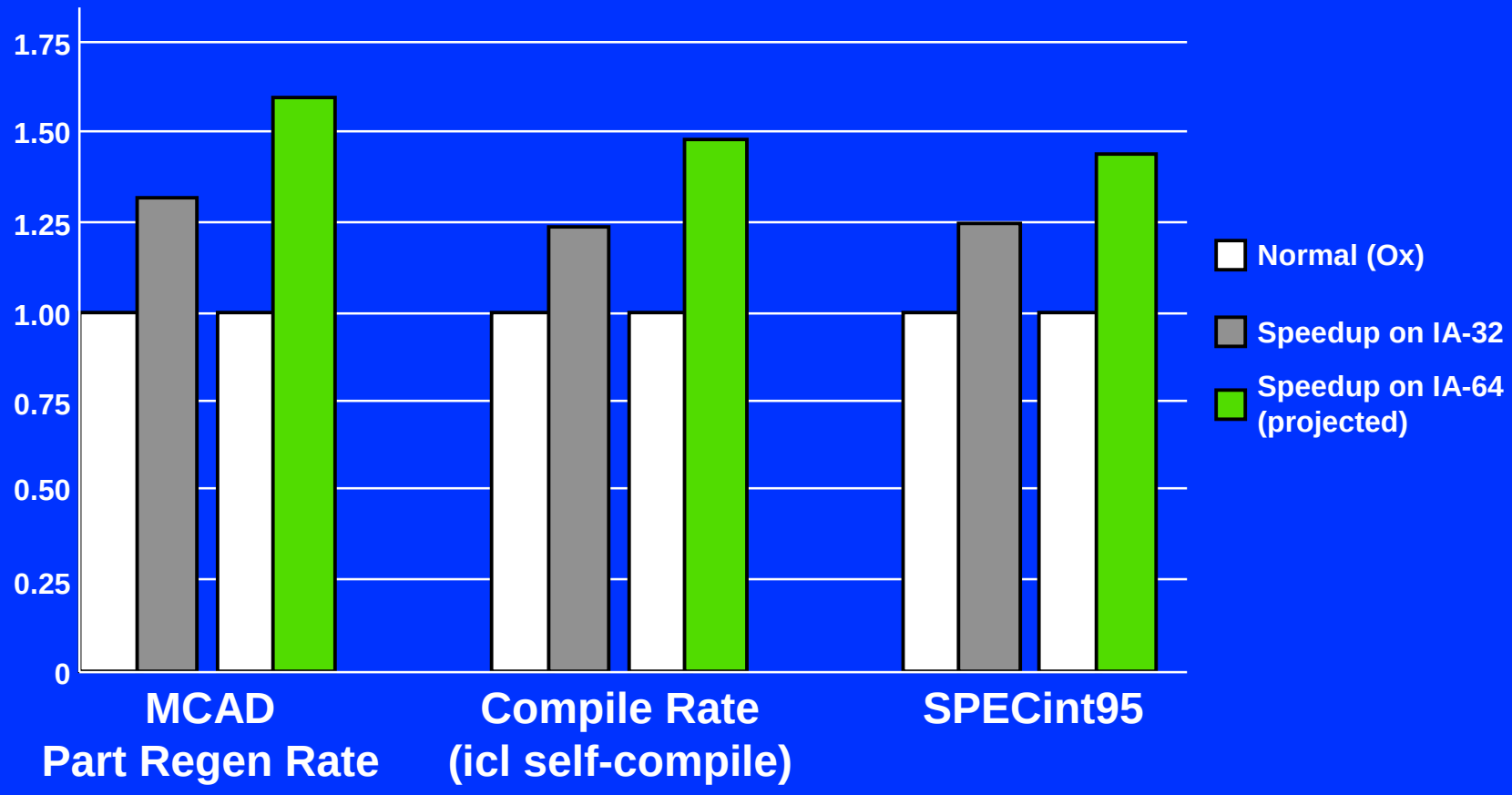
- Code layout for i-cache
- Static and dynamic profile information
- Improve usage of Resister Stack Engine
- Tune usage of predication and speculation!
- Improve branch prediction
- Inline frequently used functions only

Using IPO and PGO

- Available now on IA-32
- Greater impact is available on IA-64
- Very synergistic optimizations
  - Plan to use PGO and IPO together
- Plan to utilize in build and QA cycle

See IDF Session: Optimizing IA-64 Software Performance

PGO/IPO Speedups



PGO/IPO Benefits
Much Greater on IA64

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Mixing IA-64 and IA-32

- Use standard IPC between IA-64 and IA-32 processes (further details in backup slide)
- May be useful for dealing with 3rd party dependencies
- However …
  - no support for in-process mixing
  - should only be used when performance isn't critical

Mgt Planning for IA-64

- Start UDM practices Now!
  - Don’t wait for IA-64 release
- QA stress tests much harder/longer:
  - Fatter machines, bigger datasets, longer runs
  - New level of functionality testing (never had a 5 GB assembly to test)
  - Plan to allow PGO – dual build cycle
- Delivery plans
  - New binary (new CD? Or coexist with IA-32?)

For More Information

Intel IA-64 information:

- Primary portal: *http://developer.intel.com/design/IA-64*
- "IA-64 Application Developer's Guide," Literature #245188-00
- IA-64 Computer Based Tutorials
  http://developer.intel.com/vtune/cbts/cbts.htm

Other IA-64 information:

- IDF Tracks: Porting to Win64*/Monterey*/Linux* on IA-64
- Unified Data Model Rationale:
  http://www.opengroup.org/public/tech/aspen/lp64_wp.htm

What is an Intel® Application Solution Center (ASC)?

ASC is a premier technical center that offers software developers consultation services, tools, and support for server and workstation applications performance-tuning and porting assistance on current and future Intel® Architecture-based systems.

ASC Strategic Importance for IA-64

- ASCs provide critical *technical support* to customers during transition to IA-64
- ASCs provide *early access* to SDVs for customers to execute, debug IA-64 software
- ASCs offer software developers a *competitive edge* with leading applications built to take advantage of all IA-64 robust features

Call to Action

- ***Start*** **using a Unified Data Model**
- ***Make*** **a plan to address key issues**
- ***Seek assistance*** **through an IA-64 Application Solution Center**
  http://developer.intel.com/software/asc


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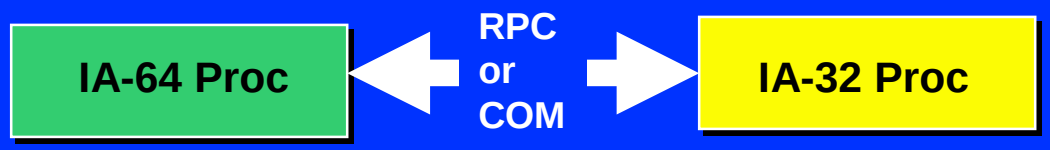
Backup

COM or RPC for Mixed Binary Communication on Win64

- Use COM or RPC (which COM is built on) for interprocess communications
- Move IA-32 DLLs to another process
- Easy to do. Can be automated.
- Use only when RPC overhead is well amortized



Ref: Search for “64-bit and 32-bit Processes” in MSDN/Platform SDK/Win64 Programming Preview