Application Program Interface

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Strategic Software Organization

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SiliconGraphics
Computer Systems

OpenMP

Outline

- Motivation for the OpenMP initiative
- Overview of OpenMP
- OpenMP Organization
- Salient features of the API
- Silicon Graphics OpenMP Products
- Future Directions

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Motivation

- No portable standard for shared memory parallelism
  - Each SMP vendor has proprietary API
  - X3H5 and PCF efforts failed
- Portability only through MPI
- Parallel application availability
  - ISVs have big investment in *existing* code
  - New parallel languages require major investment

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OpenMP Overview

- **Shared memory multiprocessing API**
  - Similar to MIPSPro "libmp": Directives , library routines
  - Constructs for enabling scalability
- **Portable standard: Unix and NT**
  - SGI
  - Intel
  - DEC
  - IBM
  - HP
  - Sun
  - Sequent
  - ASCI
  - Kuck & Associates
  - Portland Group
  - NAG
  - EPC
  - ABSOFT
  - Several Application Software Vendors

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OpenMP Organization

- OpenMP Architecture Review Board (OARB): governing body
- Led by SGI: current Chair of OARB
- Incorporation in progress
  - vendor neutral non−profit: www.openmp.org
- Fortran v1.0 Specification: October ’97
- C/C++ v1.0 Specification: August ’98
- Validation Suite for Fortran
- Supercomputing ’98

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Salient Features of the API

- Fine and Coarse Grain Parallelism
  - Loop level parallelism with standard directives
  - Scalable algorithms without message passing
  - Standardize existing practice, reduce time to market
- Allow incremental parallelization
- Provide access to strengths of shared memory
  - Exploit cache−coherent scalable hardware

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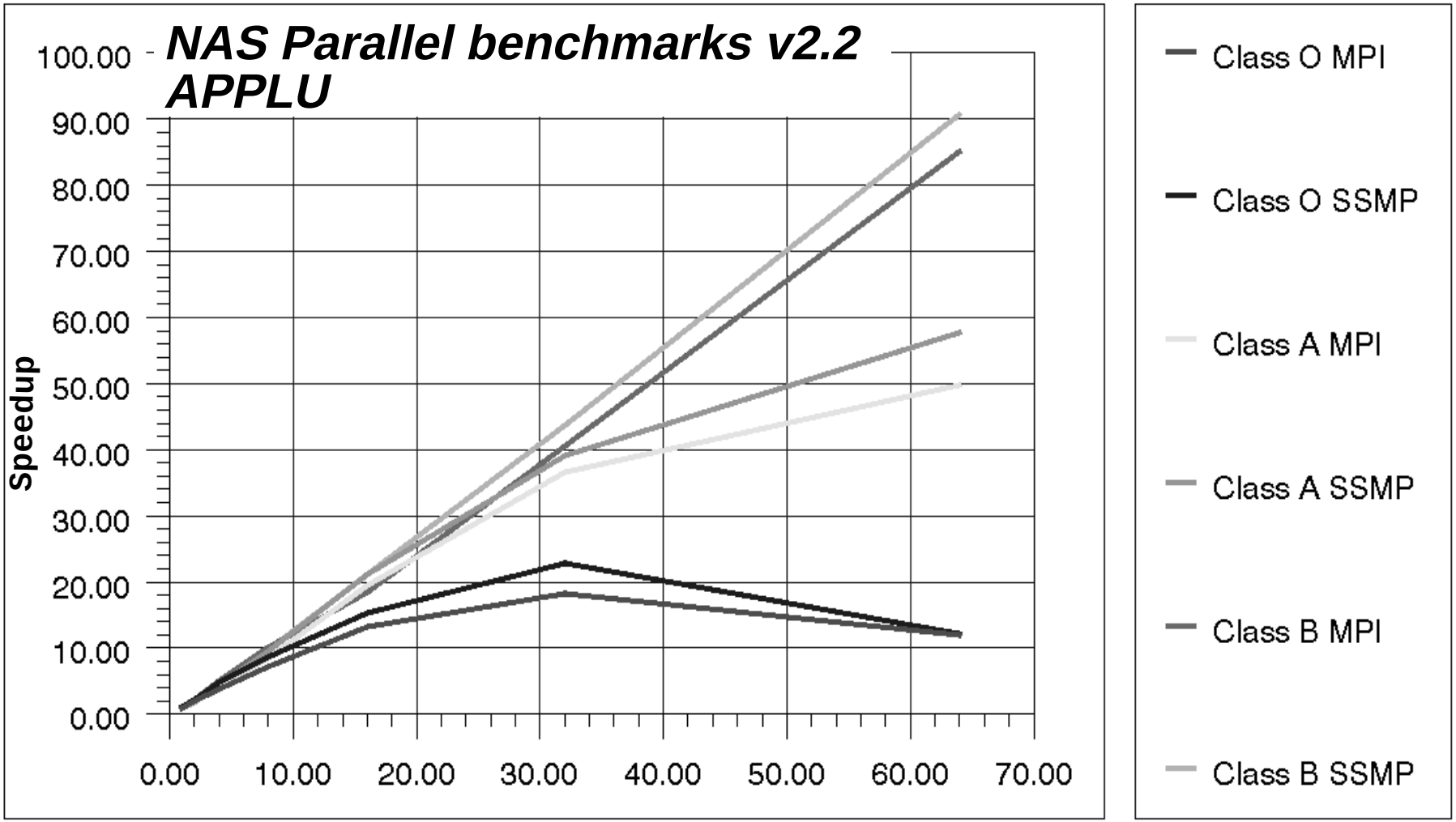
Scalability on Origin2000



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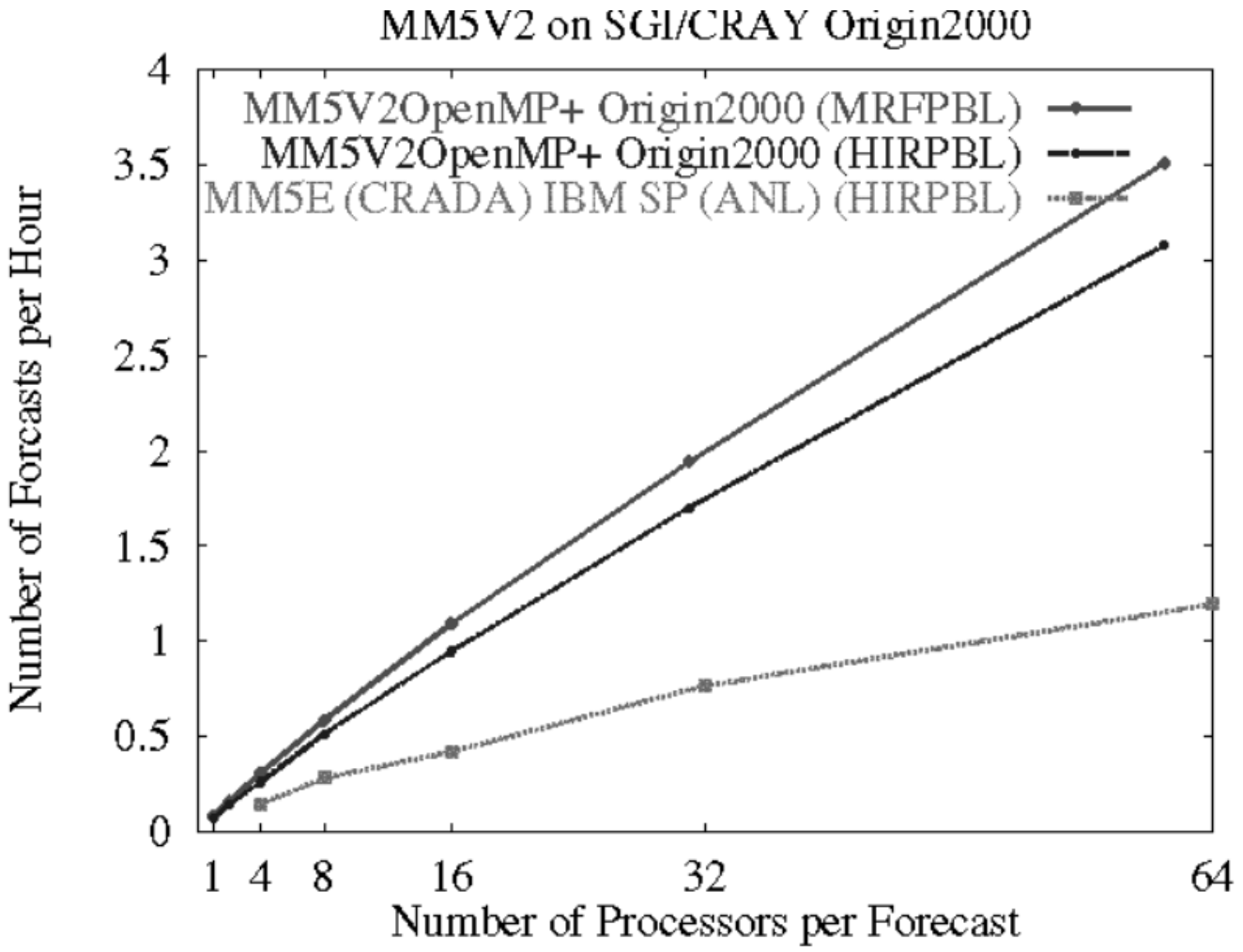
MM5 on Origin2000



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Scalability in shared memory

- Scalability is a function of the unit of work
  - Fine grain ⟷ limited scalability
  - Coarse grain ⟷ better scalability
- Algorithms & data structures determine scalability ... not the programming paradigm
- Shared memory parallelism does not imply loop level parallel
- Enabling scalability: SPMD parallel regions with *orphanable* directives

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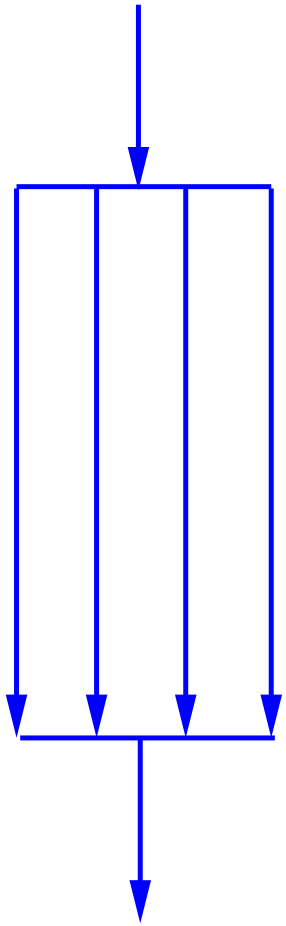
Parallel Regions

```
      program main
      :
!$OMP PARALLEL DEFAULT(PRIVATE)
      :
!$OMP BARRIER
      call work(...)
      :
!$OMP ATOMIC
        X(L(i)) = X(L(i)) + tmp
      enddo
!$OMP END PARALLEL
      :
      end
```



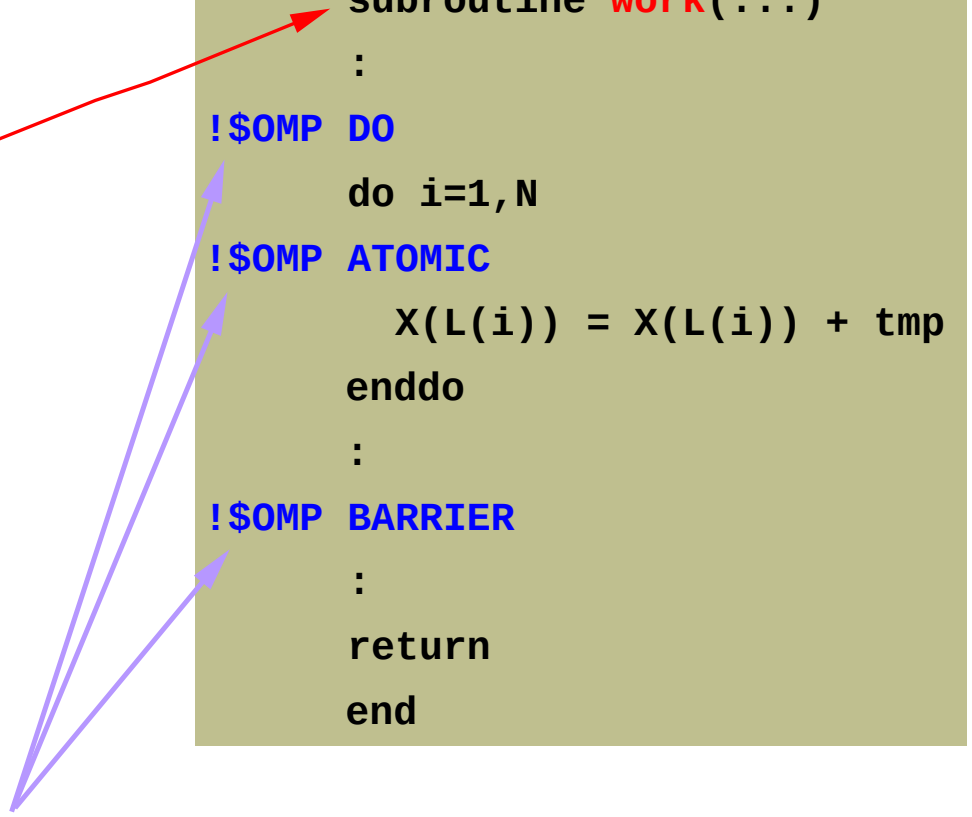
Orphaning of Directives

file1.f

```
      program main
      :
!$OMP PARALLEL DEFAULT(PRIVATE)
      :
      call work(...)
      :
!$OMP BARRIER
      :
!$OMP END PARALLEL
      :
      end
```

file2.f

```
      subroutine work(...)
      :
!$OMP DO
      do i=1,N
!$OMP ATOMIC
        X(L(i)) = X(L(i)) + tmp
      enddo
      :
!$OMP BARRIER
      :
      return
      end
```



Orphaned directives

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Functionality

- Barriers
- Critical Sections
- Flush Synchronization
  - roll your own point to point synchronization
- Master Sections
- Single Sections
- Threadprivate: Taskcommon
- Default Variable Scoping

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Irix Platform Products

- **MIPSPro 7.2.1 Fortran compilers**
  - **Performance focused implementation: scaling to large number of processors**
  - **Complete implementation + SGI extensions**
- **Workshop ProMPF tools to assist in parallelization**
  - **Trouble shoot performance problems with OpenMP aware tools**

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SGI's OpenMP Extensions

- Performance extensions only
- Complete support for NUMA directives
  - `c$sgi distribute` and variations
- Continue usage of non−MP directives
  - `c*$* {fill,align}_symbol` and variations
- Extensions for scaling
  -
```
c$sgi& nest(i,j,k)
      do k=1, nz
         do j=1, ny
            do i=1, nx
```

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Interoperability

- **OpenMP can be intermixed with:**
  - **MPI and PVM to enable Hierarchical models**
  - **Automatic Parallelization (−pfa)**
  - **Libmp: doacross and PCF directives**
  - **Autotasking directives (−cray_mp)**
  - **shmem and pthreads NOT supported in this version**
- **Precedence:**
  - **Mixed in same PU**
  - **Last directive binding**

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Future of OpenMP

- C/C++ specification:
- Validation suite
- C/C++ compilers: MIPSPro 7.3
- Extend specifications
  - Fortran 90/95 Issues
  - Memory consistency model
  - Parallel I/O issues
  - Standardize NUMA directive, templates

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Further Reading

- "OpenMP: An Industry−Standard API for Shared−Memory Programming", Leo Dagum and Ramesh Menon, *IEEE Computational Science & Engineering*, January−March 1998, Volume 5, Number 1, pp. 46−55.
- **http://www.sgi.com/Technology/OpenMP**
- **http://www.openmp.org**