HPF: Language, Compilers and Environments

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1. HPF Status Report
2. Problems with HPF 1
   - performance, missing features, tools
3. Responses
   - HPF enhancement activities
   - Language, compiler, and tool research
4. Future Directions

Status of Scalable Parallelism

- **Dream**
  - virtually limitless computing power at low cost
  - performance scalable from one to thousands of processors
  - easy portable programming
- **Reality**
  - successful at only moderate levels of scalability
  - modest progress in programmability and scalability
  - limited penetration in industry
    - independent software vendors (ISVs) still reluctant
    - limited protection of programming investment
- **Remedy: Architecture-Independent Programming**
  - a programming language and its compilers support architecture-independent parallel programming if
    - compiled code ≅ hand code for same algorithm for each target architecture

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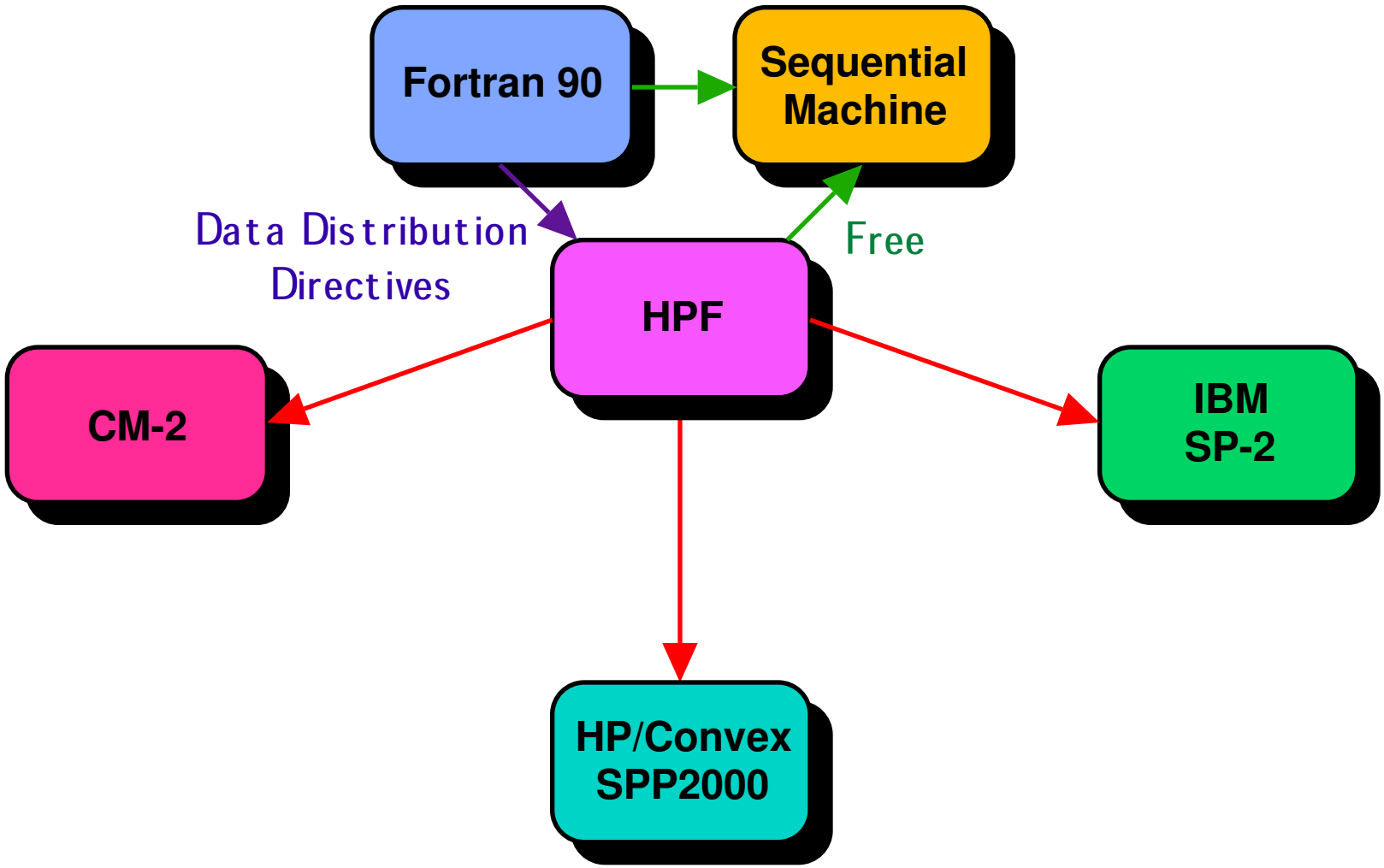
HPF Goals

- **Support for Scalable Parallel Systems**
  - scaling from one to thousands of processors
- **Focus on Data Parallelism**
  - parallelism through subdivision of data domain
- **Machine Independent Programming Support**
  - object program achieves performance comparable to hand-coded MPI on each target machine on the same algorithm
- **High Level of Abstraction**
  - more accessible programming model
    - single thread of control
    - shared memory
    - implicit generation of communication

HPF Strategy



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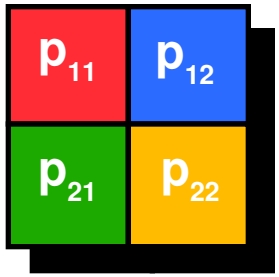
HPF Language

- **Fortran 90 + Data Distribution**

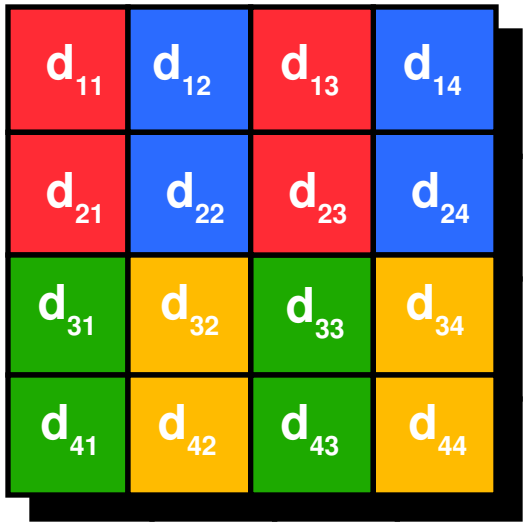
```
!HPF$  TEMPLATE D(256,256)              virtual processor array
!HPF$  ALIGN A(I,J) WITH D(I+1,J)       align data elements
!HPF$  DISTRIBUTE D(BLOCK,CYCLIC)       map to processors
```

- **Explicit and Implicit Parallelism**
  - Fortran 90 array statements, DO loops
  - "owner computes"
- **Extended looping and aggregate assignment**
  - FORALL (single-statement and block)
  - DO INDEPENDENT
- **HPF Library**
  - scatter, gather, reduction, segmented scan
- **Extrinsic Interface**
  - permits calls to message passing, other languages

(Block, Cyclic) Distribution



Processors



Template Elements

HPF Sample Program

```
      REAL A(1023,1023), B(1023,1023), APRIME(511,511)
!HPF$ TEMPLATE T(1024,1024)
!HPF$ ALIGN A(I,J) WITH T(I,J)
!HPF$ ALIGN B(I,J) WITH T(I,J)
!HPF$ ALIGN APRIME(I,J) WITH T(2*I-1,2*J-1)
!HPF$ DISTRIBUTE T(BLOCK,BLOCK)

!HPF$ INDEPENDENT, NEW(I)
      DO J = 2, 1022  ! Multigrid Smoothing Pass (red-black relaxation)
!HPF$   INDEPENDENT
        DO I = MOD(J,2), 1022, 2
          A(I,J) = 0.25*(A(I+1,J) + A(I+1,J) + A(I,J-1) + A(I,J+1)) + B(I,J)
        END DO
      END DO

!HPF$ INDEPENDENT, NEW(I)
      DO J = 2, 510   ! Multigrid Restriction
!HPF$   INDEPENDENT
        DO I = 2, 510
          APRIME(I,J) = 0.05*(A(2*I-2,2*J-2) + 4*A(2*I-2,2*J-1) + &
     &       A(2*I-2,2*J) + 4*A(2*I-1,2*J-2) + 4*A(2*I-1,2*J) +
     &       A(2*I,2*J-2) + 4*A(2*I,2*J-1) + A(2*I,2*J))
        END DO
       END DO

       ! Multigrid convergence test
       ERR = MAXVAL( ABS(A(:,:)-B(:,:)) )
```

Status

- **Bad News**
  - Acceptance of language has been slow in coming
    - MPI has achieved penetration much faster
    - compilers complex and not yet mature
    - performance was initially disappointing
    - additional features needed
- **Good News**
  - Compilers now available for every HPC platform
  - Applications beginning to emerge
  - Promising benchmark results

HPF Commercial Interest

- **Announced HPF Products**

  Applied Parallel Research
  CDAC
  Cray Research
  Digital Equipment
  Fujitsu
  Hitachi
  HP
  IBM
  Intel
  Meiko
  Motorola
  NA Software
  NEC
  Pacific Sierra Research
  Portland Group
  Sun
  Transtech

- **Announced HPF Efforts**

  ACE
  Lahey
  NAG
  nCUBE

- **Interested**

  EPC
  SGI
  Tera

HPF Usage

- **Installations**
  - PGI reports over 125 site licenses
  - NCSA: PGI on SGI is migration platform for CM-5
- **Benchmarks**
  - NAS Benchmarks: PGI compiler within factor of 2 (or better) of MPI
- **Real Applications**
  - NOAA, Princeton: Modular Ocean Model (100K lines)
  - Amoco: Falcon Reservoir Model (20K lines)
  - MATRA BAe Dynamics: AEROLOG (10K lines)
  - Quetzal: EPIC Crash Model (125K lines)
  - NCSA, UIUC: RIEMANN TVD and ENO Flow Code (50K lines)
  - U New Mexico: DFT Density Function Theory Code (6K lines)
  - MIT Earth Atmospheric and Planetary Science: Eulerian Ocean Model (3K lines)
  - Delft Univ TNO: Wish 3D CFD code (125K lines, in progress)
  - U Houston: N-body Simulation (4K lines)
  - UIUC, Civil Eng: Nonlinear Multigrid Code (1K lines)
  - CRS4: GeoComp Seismic Migration Code

Problems for HPF

- **Compilers slow to mature**
  - Fortran 90 features supported inconsistently
  - compilation for highest efficiency complex
  - initially, efficiency of object programs unsatisfactory
  - early users may become discouraged
- **Library support lacking**
  - no CMSSL equivalent
- **Needed features are missing**
  - support for irregular problems
  - task parallelism
  - high performance input/output
- **Complex relationship between program and performance**
  - explanatory and diagnostic tools are needed

HPF Enhancement Activities

- **HPF 2 Language Standard**
  - Core Language: emphasis on implementable performance
    - redistribution and realignment moved
  - Approved Extensions: future features
    - support for irregular distributions
    - computation distribution via ON clause
    - task parallelism
    - new extrinsic modules and interoperability components
- **Library Development**
  - effort to build interfaces to scientific libraries
    - linear algebra (Dongarra) and FFT (Johnsson)
    - definition effort underway, implementation funding sought
- **HPF User Group**
  - First meeting: February 24-26, 1997 in Albuquerque

Specific Language Changes

- **Changes in HPF 2 from HPF 1.1**
  - Explicit interfaces required if remapping.
  - Intrinsic, commutative reductions.
  - Pointers cannot be mapped or point to mapped objects
  - Mapping of aggregate covers eliminated from the language
  - DYNAMIC and related features (REALIGN, REDISTRIBUTE) moved to Approved Extensions
- **Approved Extensions**
  - DYNAMIC and related features (REALIGN, REDISTRIBUTE)
  - Extrinsics: HPF_SERIAL, HPF_LOCAL
  - Pointer mapping
  - All other new features passed in second reading

    irregular support, computation partitioning with ON clause, task parallelism

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D System Research Responses

- **Compiler Optimization Research**
  - dHPF research compiler
    - new optimizations, new machine targets (e.g., DSM)
  - collaboration with Portland Group
- **New Features**
  - support for irregular problems
    - collaboration with Joel Saltz
  - scalable I/O
    - part of SIO initiative
- **D System Tools**
  - support for construction of efficient HPF programs
    - intelligent editor displaying compiler feedback
    - display of run-time information from Pablo (Dan Reed)

Future Research Areas

- **Support for Heterogeneous Parallelism**
  - language extensions for specification of task/object parallelism
  - automatic load balancing
- **Java Compilation**
  - compilation for high-performance servers
    - freedom from portable Java restrictions
  - interprocedural analysis framework
  - autoparallelization
- **Compiler Support for Problem-Solving Environments**
  - PSE Toolkit: front-end plus interprocedural analysis
- **Petaflops Computing**
  - emphasis on 10M-way parallelism and latency management

Summary

- **HPF compilers emerging**
  - language available on nearly every parallel system
- **HPF 1 has some problems**
  - performance
  - missing features
    irregular support, task parallelism, I/O
  - programming tools and libraries needed
- **HPF 2 addresses language issues**
  - focus on implementable language for performance
  - advanced features as Approved Extensions
- **CRPC research is developing new HPF technologies**
  - advanced compiler optimization
  - support for new language features
  - libraries and programming tools
  - technology transfer to compiler vendors and end users