A Tool Framework for Static and Dynamic Analysis of Object-Oriented Software with Templates

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Outline

- **Context**
- Program Database Toolkit (PDT)
- Applications Using PDT
- PDT Availability

Context

- High-performance computing environments
- Infrastructure for large-scale scientific computation
  - Object-oriented frameworks
  - Scalable run-time systems
  - Software component architectures

Problem

- Automatic instrumentation of C++ source code

Difficulties with C++ Templates

- Template parsing is a challenge for some compilers
- Output from compiler front end may not include template info
- Templates may be instantiated at pre-link time
- Original template must be instrumented

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Program Database Toolkit (PDT)

Edison Design Group (EDG) Front End

- Parses a C++ source file
- Creates an intermediate language (IL) tree

IL Analyzer

- Processes the intermediate language tree
- Creates a structured “program database” file

Program Database (PDB)

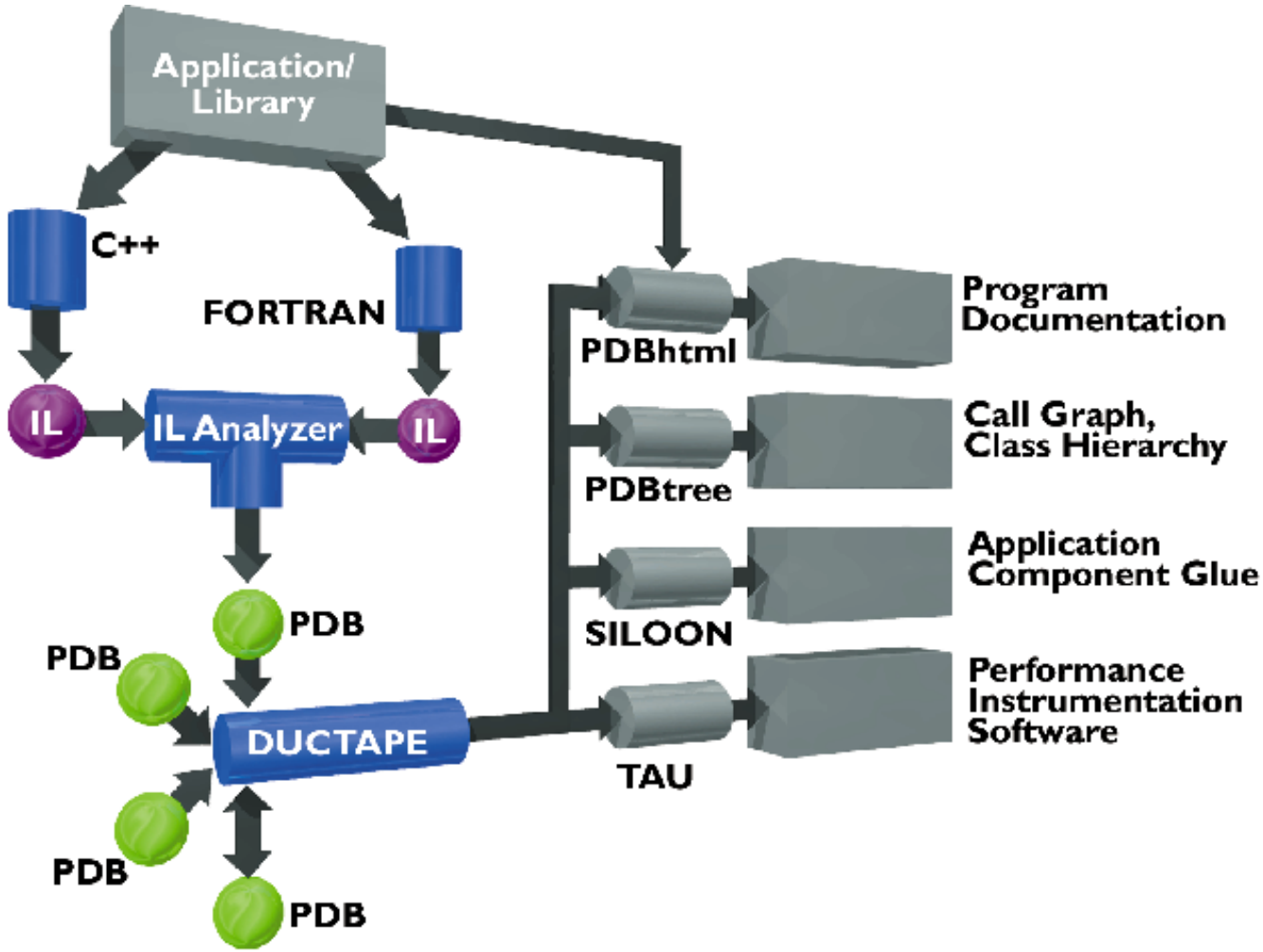
- Can be easily and efficiently read by a programming or a scripting language

DUCTAPE

(C++ program Database Utilities and Conversion Tools APplication Environment)

- Processes and merges PDB files
- Provides object-oriented, C++ interface to the PDB file

PDT Architecture



Program Database (PDB)

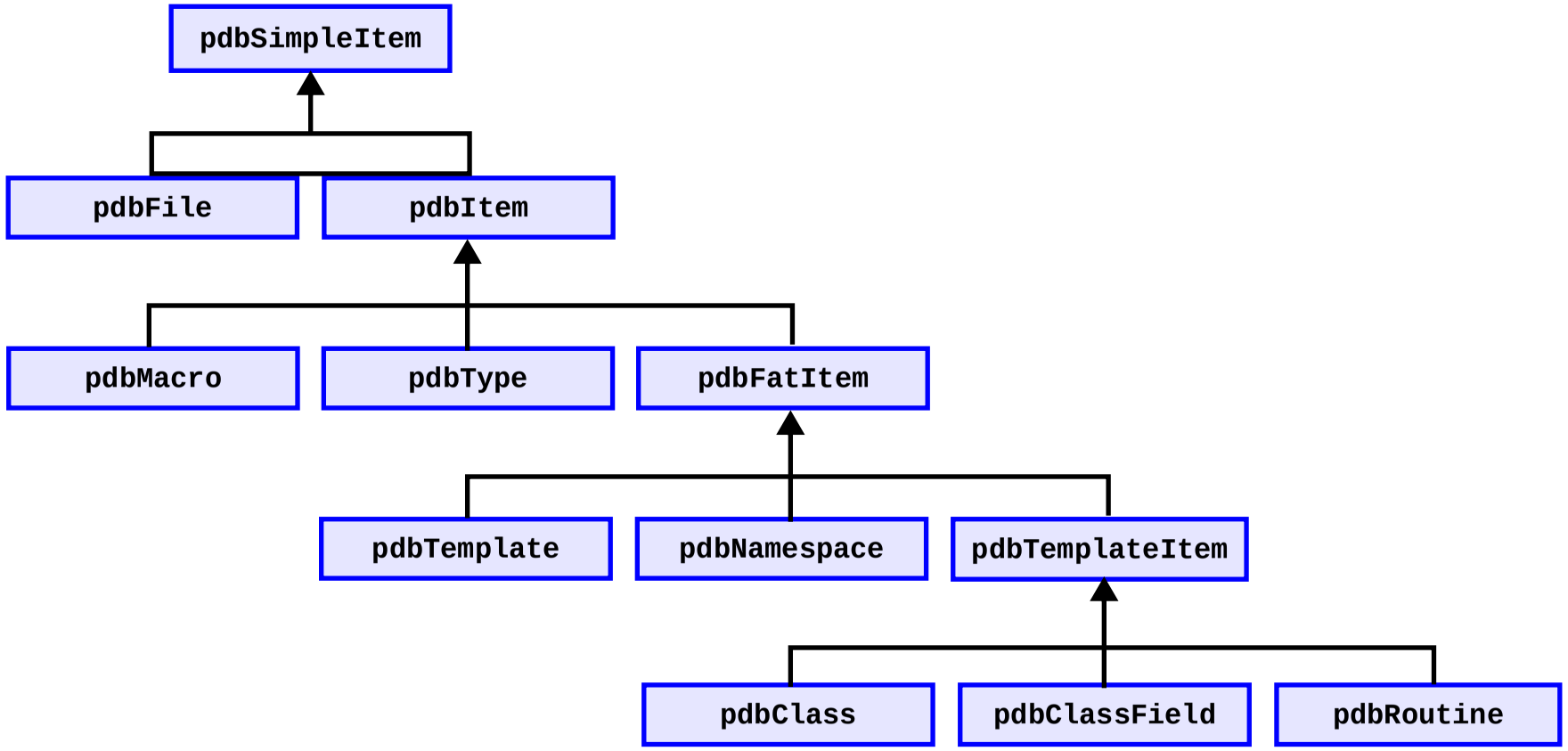
PDB comprises the “interface” of the original source:

- Items describing functions, classes, other programming language constructs
- Information on template instantiations

Item Type	Attributes of Item
all ITEMs	**source position**
HEADER	**<PDB 1.0>**
SOURCE FILES	**files included by source file**
ROUTINES	**template from which instantiated, parent class or namespace, access mode, signature, functions called, characteristics specifying linkage, storage class, virtuality, *etc*.**
CLASSES	**template from which instantiated, parent class or namespace, access mode, direct base classes, friend classes and functions, characteristics, member functions, information on other members, including access, kind, and type**
TYPES	**parent class or namespace, access mode, various characteristics, depending on type: *e.g.*, for function types, return type, parameter types, presence of ellipsis, and exception class IDs**
TEMPLATES	**parent class or namespace, access mode, kind, text of template**
NAMESPACES	**members of namespace or alias**
MACROS	**kind, text of macro**

DUCTAPE

The **DUCTAPE** C++ library provides access to **PDB** files via the class hierarchy:



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Applications Using PDT

- Simple Utility
- Source-to-Source Translation
- Code Generation
- Static Analysis and Documentation Generation

Simple Utility

Excerpt from **DUCTAPE**'s ***pdbtree*** utility

```
static void printFuncTree(const pdbRoutine *r, int level) {
    r->flag(ACTIVE);
    pdbRoutine::callvec c = r->callees();
    for (pdbRoutine::callvec::iterator it=c.begin(); it!=c.end(); ++it) {
      const pdbRoutine *rr = (*it)->call();
      if ( level != 0 || rr->callees().size() ) {
        cout << setw((level-1)*5) << "";
        if ( level ) cout << "`--> ";
        cout << rr->fullName();
        if ( (*it)->isVirtual() ) cout << " (VIRTUAL)";
        if ( rr->flag() == ACTIVE ) {
          cout << " ..." << endl;
        } else {
          cout << endl;
          printFuncTree(rr, level+1);
        }
      }
    }
    r->flag(INACTIVE);
}
```

Source-to-Source Translation

PDT assists in automatic instrumentation of C++ source for

TAU (Tuning and Analysis Utilities) Instrumentor:

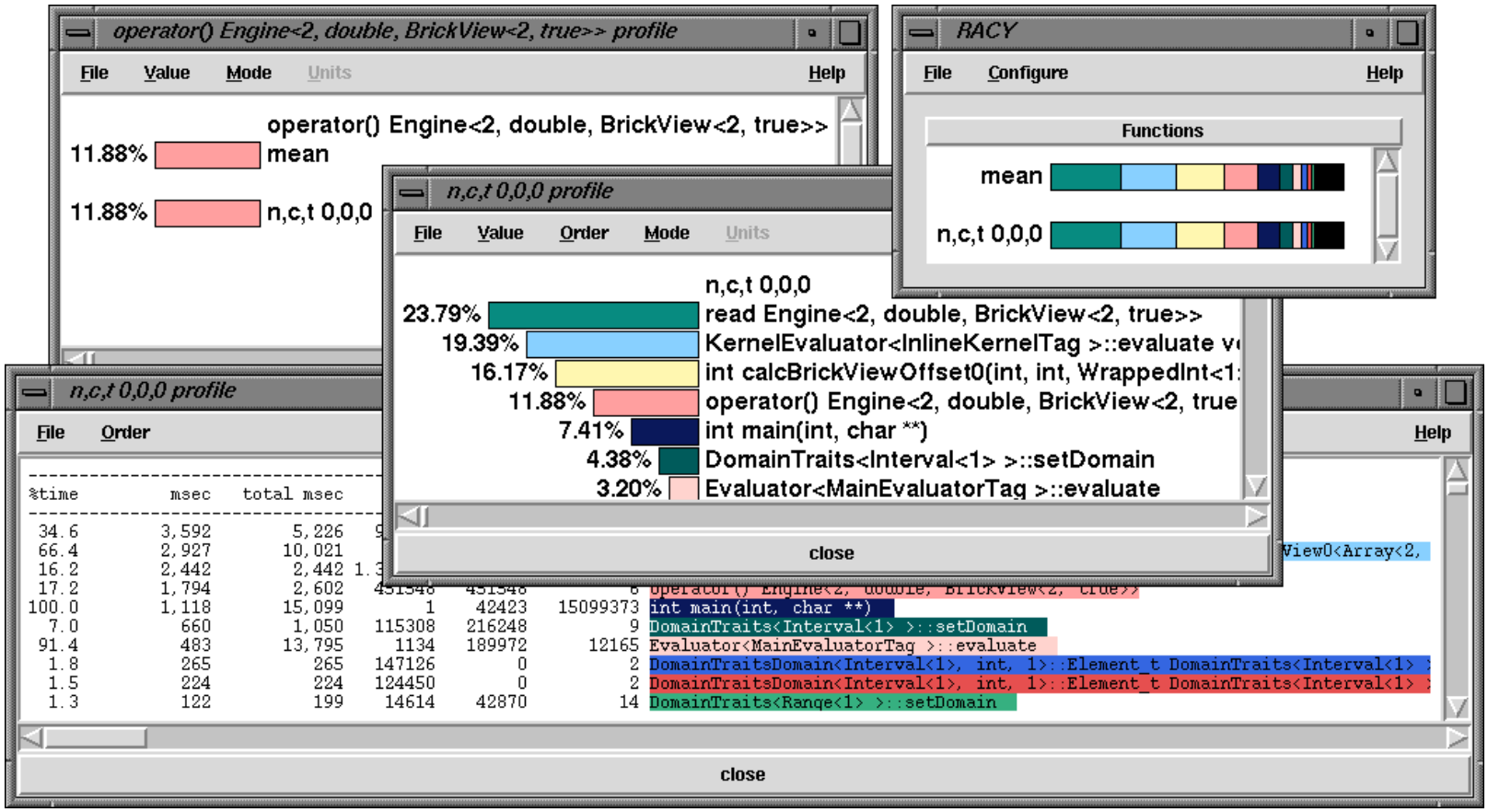
- Iterates through PDB list of functions and templates
- Generates and inserts TAU profiling macros in source code
- Application links with TAU library to create profile data files

```
template <class T>
class vector {
public:
    vector (int size) {
        TAU_PROFILE ("vector::vector ( )", CT (*this), TAU_USER);
    ...

    }
}
```

Source-to-Source Translation (2)

TAU automatically instrumented POOMA's Krylov solver using **PDT**

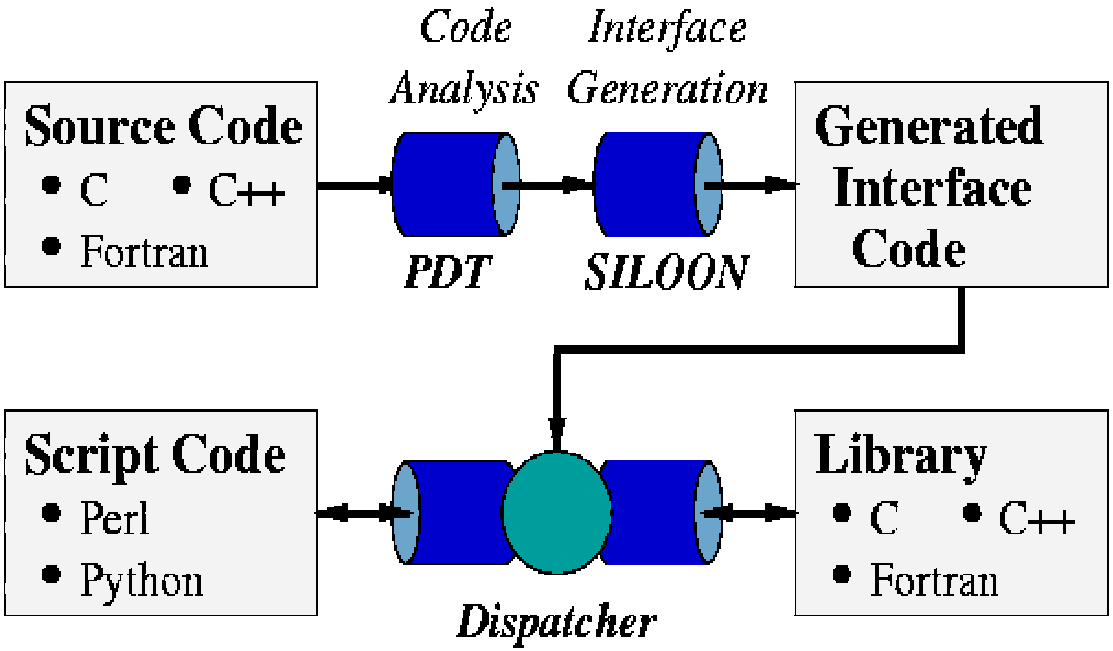


Code Generation

PDT assists in generating glue and skeleton code for

SILOON (Scripting Interface Language for Object-Oriented Numerics):

- Automates access to C++ and Fortran libraries from Python and Perl
- Enables rapid prototyping of scientific codes using scripting languages



Static Analysis and Documentation Generation

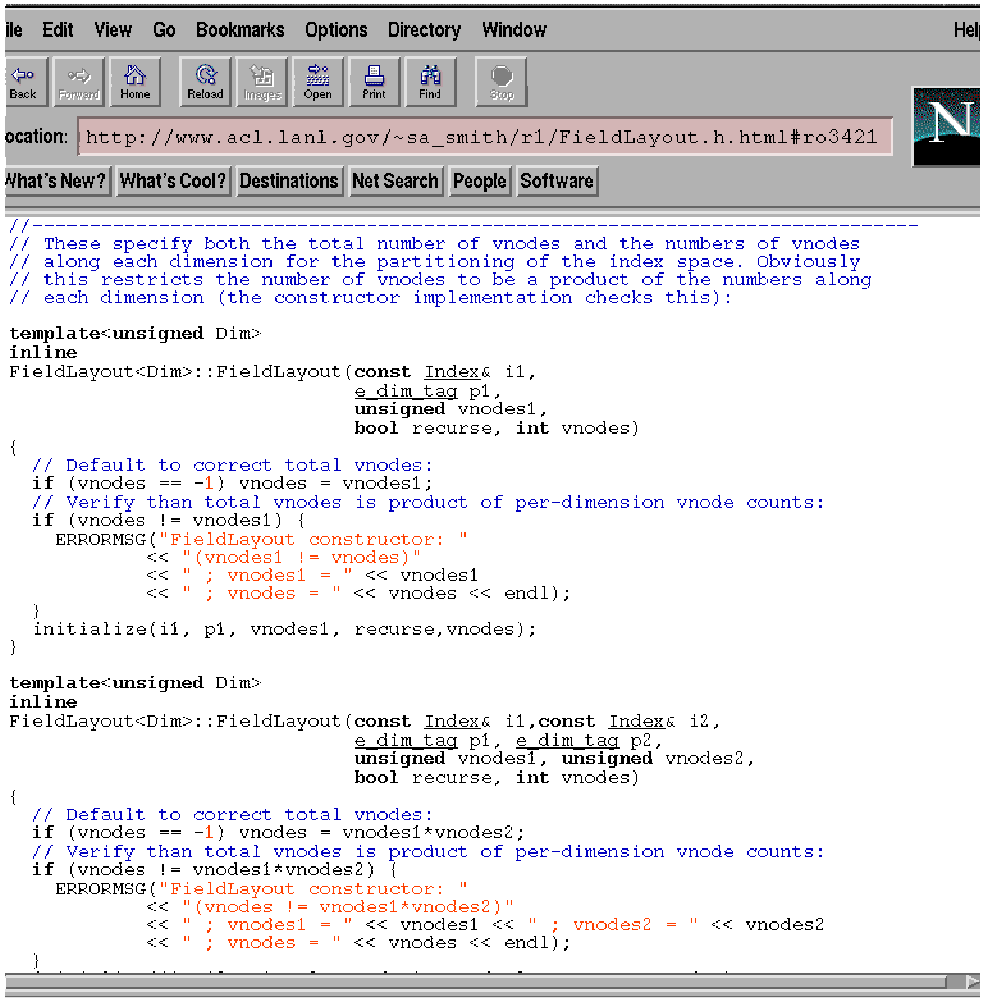
PDT assists in static analysis

Four **DUCTAPE** applications have been developed:

- ***pdbconv*** converts PDB files to a more readable format
- ***pdbmerge*** merges PDB files from separate compilations
  Merges template instantiations from separate compilations
- ***pdbtree*** prints file inclusion, class hierarchy, and call graph trees
  Supersedes TAU browsers
- ***pdbhtml*** “htmlizes” C++ source

Static Analysis and Documentation Generation (2)

pdbhtml output




```
//-------------------------------------------------------------------------
// These specify both the total number of vnodes and the numbers of vnodes
// along each dimension for the partitioning of the index space. Obviously
// this restricts the number of vnodes to be a product of the numbers along
// each dimension (the constructor implementation checks this):

template<unsigned Dim>
inline
FieldLayout<Dim>::FieldLayout(const Index& i1,
                              e_dim_tag p1,
                              unsigned vnodes1,
                              bool recurse, int vnodes)
{
  // Default to correct total vnodes:
  if (vnodes == -1) vnodes = vnodes1;
  // Verify than total vnodes is product of per-dimension vnode counts:
  if (vnodes != vnodes1) {
    ERRORMSG("FieldLayout constructor: "
             << "(vnodes1 != vnodes)"
             << " ; vnodes1 = " << vnodes1
             << " ; vnodes = " << vnodes << endl);
  }
  initialize(i1, p1, vnodes1, recurse,vnodes);
}

template<unsigned Dim>
inline
FieldLayout<Dim>::FieldLayout(const Index& i1,const Index& i2,
                              e_dim_tag p1, e_dim_tag p2,
                              unsigned vnodes1, unsigned vnodes2,
                              bool recurse, int vnodes)
{
  // Default to correct total vnodes:
  if (vnodes == -1) vnodes = vnodes1*vnodes2;
  // Verify than total vnodes is product of per-dimension vnode counts:
  if (vnodes != vnodes1*vnodes2) {
    ERRORMSG("FieldLayout constructor: "
             << "(vnodes != vnodes1*vnodes2)"
             << " ; vnodes1 = " << vnodes1 << " ; vnodes2 = " << vnodes2
             << " ; vnodes = " << vnodes << endl);
  }
```

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Implementation Summary

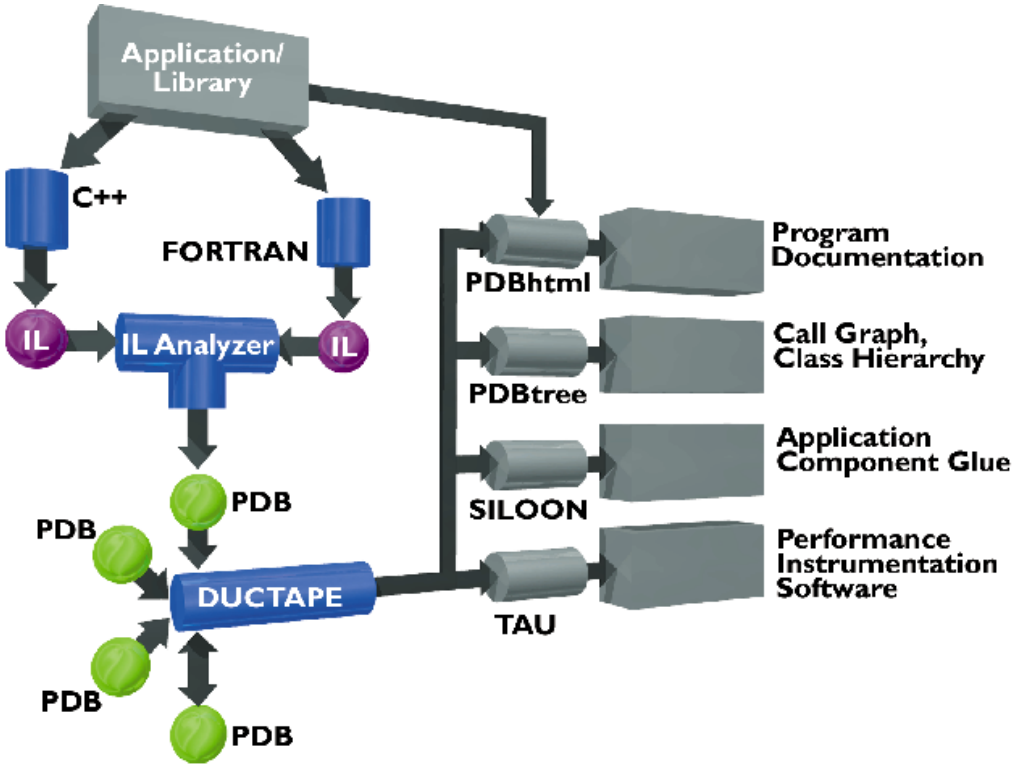
Programming languages supported:

- **C/C++**
- **Fortran 90**

Platforms supported:

Architecture	Platform	Operating System
hp9000s700	**HP PA-RISC 1.1**	**HP-UX 10.20**
linux	**Intel i686**	**RedHat Linux 5.2**
rs6000	**IBM SP-2**	**AIX 4.2.1**
sgi32	**SGI R4400 IP22**	**IRIX 6.5.4**
sgin32	**SGI R10000 IP25**	**IRIX 6.5.4**
sgi64	**SGI R10000 IP25**	**IRIX 6.5.4**
solaris2	**SUN sun4m**	**Solaris SunOS 5.6**
t3e	**SGI Cray T3E**	**Unicos MK 2.0.4.61**

Program Database Toolkit (PDT)



http://www.acl.lanl.gov/pdtoolkit/

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