DÔOM User Guide

H. Greenlee, J. Hobbs, S. Snyder, V. White

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## Contents

1 **Overview of DÔOM** .................................................. 4
   1.1 The DÔOM Object Model ........................................... 4
   1.2 The DÔOM Preprocessor and Dictionary Classes ................. 5
       1.2.1 Undefined Objects and Schema Evolution .................. 5

2 **DÔOM Object Model Classes and Types** .......................... 6
   2.1 Atomic Types .................................................... 6
   2.2 Container Classes ............................................... 6
       2.2.1 STL Container Classes .................................... 7
       2.2.2 Hash Table Classes ....................................... 7
       2.2.3 Other C++ Types ........................................... 8
       2.2.4 DÔOM Container Classes ................................... 8
       2.2.5 User-Defined Collections ................................. 11
   2.3 DÔOM String Class ............................................... 12
   2.4 DÔOM Reference Classes ........................................ 13
       2.4.1 Reference Counting ....................................... 13
       2.4.2 dO_Ref<T> Methods ....................................... 14
       2.4.3 Restrictions .............................................. 17
       2.4.4 Name-Only References .................................... 17
       2.4.5 Reference Type Conversions ............................... 17
   2.5 C++ Bare Pointers ............................................... 18
   2.6 C++ auto_ptr Class ............................................. 19
   2.7 Transient Data in Persistent Classes ........................... 19
   2.8 DÔOM Base Class and Inheritance ............................... 20
       2.8.1 Multiple Inheritance ..................................... 21
       2.8.2 Polymorphism ............................................. 22
       2.8.3 Activate and Deactivate ................................. 22
   2.9 Class Versions .................................................. 23
2.10 How Objects Are Reconstructed .................................. 23
2.11 Nested Classes ...................................................... 24
2.12 Namespaces .......................................................... 24
2.13 Preprocessor Macros ................................................. 24
2.14 Template Classes .................................................... 25
2.15 Translated Classes ................................................... 26
2.16 ZOOM and CLHEP Classes ......................................... 30
2.17 Reserved Member Names ............................................ 31
2.18 Packed Fields ......................................................... 31
   2.18.1 DSPACK Implementation of Packed Fields ................. 33

3 DÔOM I/O Interface .................................................. 34
   3.1 Class d0Stream .................................................... 34
      3.1.1 Methods of d0Stream ...................................... 34
      3.1.2 Random Access and Keys .................................. 35
      3.1.3 Random Access Recommendations .......................... 37
      3.1.4 Methods of d0StreamDB .................................... 37
   3.2 Factory Class d0StreamFactory ................................ 39
   3.3 Output Filters .................................................... 40
   3.4 Memory buffers .................................................. 40
      3.4.1 Output ....................................................... 40
      3.4.2 Input ....................................................... 41
      3.4.3 Embedded Dictionary Records .............................. 42

4 Using DÔOM .......................................................... 42
   4.1 How to Make a Class Persistent ................................ 43
   4.2 Reference Headers ............................................... 44
   4.3 d0cint Command Reference .................................... 44
   4.4 Predefined Macros ............................................... 45
   4.5 Environment Variables For Debugging ......................... 46
   4.6 Functions for Debugging ....................................... 46

5 How to Compile and Link a DÔOM Program ....................... 46
   5.1 Requirements .................................................... 46
   5.2 Setups ........................................................... 47
   5.3 CVS Libraries .................................................... 47
   5.4 DOOM Source Code ............................................... 47
   5.5 Releases ........................................................ 48
   5.6 Becoming a Developer ........................................... 49
   5.7 DOOM Header Files .............................................. 50
   5.8 Generating Linkage Files ....................................... 51
   5.9 Controlling Generation of Linkage Information ............. 51
6 Utility Programs
  6.1 dsdump ........................................... 53
  6.2 DSpack debugger .................................. 54
  6.3 evdump ........................................... 56
  6.4 evaddindex ....................................... 57

7 Unknown Objects
  7.1 Output ........................................... 57
  7.2 Input ............................................ 57
  7.3 Copying .......................................... 58

8 Schema Evolution
  8.1 Class Names ....................................... 59
  8.2 Class Members ..................................... 59
  8.3 Conversions ...................................... 60
    8.3.1 Registering Converters .......................... 61
    8.3.2 Writing Converters ................................ 62
    8.3.3 Version Conversions ................................ 65
    8.3.4 Implicit Conversions ................................ 66
    8.3.5 Predefined Conversions ............................ 66
  8.4 nwrite .......................................... 66
  8.5 Other Points ....................................... 67

9 d0cintPragma Reference
  9.1Pragma Listing .................................... 67
  9.2Pragma Macros ...................................... 71

A Some d0_ref<T> Details .................................. 72

B Doom Dictionary Classes .................................. 73
  B.1 Atomic Types ...................................... 74
  B.2 Collections ....................................... 74
  B.3 References ....................................... 74
  B.4 Classes .......................................... 76
  B.5 Accessing the Dictionary classes .................... 76

C DSpack Specific I/O Interface .......................... 76
  C.1 DOOM to DSpack Interface Classes .................... 78
  C.2 d0StreamDSpack .................................... 78
  C.3 I/O stream to file ID mapping classes ............... 79
  C.4 Mapping classes between DOOM persistent classes and DSpack datasets 79
    C.4.1 d0om_DS::Dir .................................. 79
    C.4.2 Saveable Base Class ............................ 80
    C.4.3 d0om_DS::Class and d0om_DS::Classrep .......... 80
    C.4.4 d0om_DS::Collection ............................ 81
    C.4.5 d0om_DS::Atomic ................................ 81
1 Overview of DØOM

DØOM is an object persistency system for C++ classes. DØOM sits on top of an underlying I/O package, such as the DSPACK [1] (for sequential files) or a database. DØOM consists of the following elements.

1. Object model classes.
2. Preprocessor.
3. User I/O classes.
5. DSPACK interface classes.

Normally, users interact directly only with the first three of the above five items. The last two items are primarily intended for internal use by DØOM. In particular, package specific I/O calls are hidden from the user. The underlying I/O mechanism can be changed without affecting the DØOM user interface.

In addition to this guide, you should also consult the C++ headers for the classes which you are going to use. In most cases, the details of the interface are described only in the headers.

1.1 The DØOM Object Model

The DØOM object model is loosely based on the ODMG object model for object oriented databases [2]. The DØOM object model requires that persistent classes have the following properties.

1. Persistent classes inherit, directly or indirectly, from the persistent base class d0_Object.

2. Persistent classes are composed of the following elements:
   
   (a) Atomic types (int, float, d0_Int, d0_Float, etc.).
   (b) C++ fixed length arrays.
(c) DOOM container classes (e.g. d0_Vector<T>).

d) The C++ standard container classes deque, list, vector, set, multiset, map, multimap, stack, queue, priority_queue, and valarray.

e) The additional standard C++ types bitset and complex.

f) DOOM strings (d0_String) or the C++ standard string class string (which can also be called basic_string).

(g) DOOM reference classes (smart pointers, d0_Ref<T>).

(h) C++ bare pointers and auto_ptr.

(i) Literal classes (non-persistent user-defined classes contained within persistent classes). Literal classes do not need to be derived from d0_Object, but must be composed of the types allowed in persistent classes.

Certain restrictions apply to the types that can be used with the standard DOOM template classes (containers and references). Refer to sections 2.2 and 2.4 for details.

Note that data member names starting with two underscores are reserved.

1.2 The DOOM Preprocessor and Dictionary Classes

The DOOM preprocessor is borrowed from the cint C++ interpreter, which is distributed as part of the ROOT system [3]. The dictionary classes contain information about the structure of user classes, or in other words they contain class metadata. The DOOM preprocessor, d0cint, analyzes user’s header files and generates the code necessary to create the dictionary classes. Users do not normally invoke the dictionary classes directly. Rather, the DOOM I/O classes use the information in the dictionary classes to translate the user’s persistent objects into DSPACK or database objects, which are then read or written by the underlying I/O system. Refer to Appendix B for more information about DOOM’s dictionary classes.

1.2.1 Undefined Objects and Schema Evolution

The definition of DOOM persistent classes is fixed at compilation time (actually at preprocessing time). The universe of persistent classes that is known to a particular program is fixed at link time. Each persistent class known to DOOM has a name that is deterministically mapped onto a single DSPACK data set or database table. One DSPACK data set or database table stores data from all instances of a particular persistent class.

Ideally, when DOOM reads previously written data, the names and definitions stored in the previously written data correspond exactly to the current DOOM persistent classes. In such cases the conversion of DSPACK data into DOOM objects is straightforward. But if the DSPACK definitions do not match the compiled-in definitions, DOOM will attempt to convert the data format. DOOM can cope with simple situations such as the addition, deletion, or rearrangement of data fields. Any missing data is set to zero or null. If DOOM can’t convert the data format, a fatal error results. For more discussion on schema evolution, see Section 8.
Table 1: DOOM atomic types.

<table>
<thead>
<tr>
<th>DOOM type</th>
<th>Equivalent standard type</th>
</tr>
</thead>
<tbody>
<tr>
<td>d0_Int</td>
<td>int</td>
</tr>
<tr>
<td>d0_UInt</td>
<td>unsigned int</td>
</tr>
<tr>
<td>d0_Short</td>
<td>short</td>
</tr>
<tr>
<td>d0_USShort</td>
<td>unsigned short</td>
</tr>
<tr>
<td>d0_Long</td>
<td>long</td>
</tr>
<tr>
<td>d0_ULong</td>
<td>unsigned long</td>
</tr>
<tr>
<td>d0_Char</td>
<td>unsigned char</td>
</tr>
<tr>
<td>d0_Bool</td>
<td>bool</td>
</tr>
<tr>
<td>d0_Float</td>
<td>float</td>
</tr>
<tr>
<td>d0_Double</td>
<td>double</td>
</tr>
<tr>
<td>d0_Octet</td>
<td>unsigned char</td>
</tr>
</tbody>
</table>

It can also happen that DOOM finds a DSPACK data set or database table for which there is no corresponding persistent class (i.e. an unknown name). This situation is described in Section 7.

2  DOOM Object Model Classes and Types

This section contains a more detailed description of the DOOM object model classes and types.

2.1  Atomic Types

A complete list of DOOM atomic types is shown in Table 1. DOOM atomic types are implemented as simple typedefs. Persistent class headers may be specified using either the DOOM name or the standard name for the allowed atomic types.

Note that DSPACK does not support 64-bit integers. If you use a long type on the Alpha, it will be truncated to 32 bits on output.

2.2  Container Classes

Many types of containers can be saved. A container is represented as a one-dimensional ordered list of arbitrary length of homogeneous objects.

The type of object stored in a container should satisfy the same requirements as for a class data member. Atomic types, pointers, references, user-defined classes, and other containers are all legitimate.

Polymorphism is not allowed for objects stored in containers. The type of any object put into a container must exactly match the type of the class’s template argument. It follows that heterogeneous collections are not allowed. However, the same effect as a heterogeneous collection can be achieved by having a collection of references or pointers.
Note that some container classes can have additional state besides the container contents, such as the comparison objects for associative containers, or the allocator object for most STL containers. This additional state is not saved. You should thus be careful if you create a container with a comparison object or allocator which is not simply initialized by the default constructor.

The kinds of containers which may be saved are summarized below.

### 2.2.1 STL Container Classes

The following plain STL container classes can be saved:

- `deque`
- `list`
- `vector`
- `set`
- `multiset`
- `map`
- `multimap`
- `stack`
- `queue`
- `priority_queue`
- `valarray`

### 2.2.2 Hash Table Classes

The following hash table classes, defined in the `d0_util` package, can be saved:

- `d0_util::Hashmap`
- `d0_util::Ptrmap`
- `d0_util::Ptrset`
- `d0_util::Strptrmap`
- `d0_util::Stringset`
2.2.3 Other C++ Types

The following additional template classes from the standard C++ library may be saved:

- bitset
- complex

2.2.4 DØOM Container Classes

[Note: The classes described in this section are now in the d0_util package.]

The DØOM container classes are derived from STL containers. Table 2 table summarizes the correspondence between DØOM and STL container classes. The DØOM containers also inherit a common ODMG-like interface from a generic container class d0::Collection<T> (see Fig. 1). The ODMG-like interface is a partial implementation of the interface defined in Ref. [2]. Users can use either the STL interface or the ODMG-like interface. Note that the DØOM containers are not derived from d0::Object, and therefore can not be persistent on their own. This does imply, however, that these containers can be used apart from the rest of the persistence mechanism.

Classes that are to be stored in DØOM containers should implement the default constructor, copy constructor, destructor, and any methods required by the corresponding STL container. These typically include the assignment operator (=), equivalence operator (==), and, if appropriate, the less than operator (<). The other relational operators are derived from global template functions that are part of STL. As with any class, it is also good practice to implement the ostream insertion operator (<<).

**Iterators** DØOM contains two iterator classes, called d0::ConstIterator<T> and d0::Iterator<T>, for iterating over elements of any of the DØOM containers. The
Figure 1: Mutable container (\texttt{d0\_vector} and \texttt{d0\_List}) class diagram.
constant version of the iterator must be used for read only collections and for immutable collections (sets and multisets). The class diagram for the DOOM iterators is shown in Fig. 2. There is no inheritance relationship between the DOOM iterators and STL iterators. However, DOOM iterators fulfill the interface requirements for STL bidirectional iterators, and therefore may be used wherever STL iterators are allowed, for example in STL algorithm calls. In addition to the STL interface, DOOM iterators have an ODMG-like interface that provides some additional functionality not present in the STL interface.

DOOM iterators can be obtained from any DOOM container class using the methods `d0_begin()` and `d0_end()`. The STL methods `begin()` and `end()` return STL iterators, which can also be used for iterating over DOOM collections.

**Pointer and Reference Container Classes** Special container and iterator classes exist for collections of pointers and references. Table 3 lists these special classes and their functional equivalents. These classes exist for the technical reason that they allow more sharing of code than the ordinary classes, and hence they produce smaller code. Either kind of special collection can be used in persistent classes.

<table>
<thead>
<tr>
<th>Special class</th>
<th>Equivalent ordinary class</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>d0_PVector&lt;T&gt;</code></td>
<td><code>d0_Vector&lt;T*&gt;</code></td>
</tr>
<tr>
<td><code>d0_RWVector&lt;T&gt;</code></td>
<td><code>d0_Vector&lt;d0_Ref&lt;T&gt; &gt;</code></td>
</tr>
<tr>
<td><code>d0_PList&lt;T&gt;</code></td>
<td><code>d0_List&lt;T*&gt;</code></td>
</tr>
<tr>
<td><code>d0_RList&lt;T&gt;</code></td>
<td><code>d0_List&lt;d0_Ref&lt;T&gt; &gt;</code></td>
</tr>
<tr>
<td><code>d0_PIterator&lt;T&gt;</code></td>
<td><code>d0_Iterator&lt;T*&gt;</code></td>
</tr>
<tr>
<td><code>d0_RIterator&lt;T&gt;</code></td>
<td><code>d0_Iterator&lt;d0_Ref&lt;T&gt; &gt;</code></td>
</tr>
<tr>
<td><code>d0_Const_PIterator&lt;T&gt;</code></td>
<td><code>d0_Const_Iterator&lt;T*&gt;</code></td>
</tr>
<tr>
<td><code>d0_Const_RIterator&lt;T&gt;</code></td>
<td><code>d0_Const_Iterator&lt;d0_Ref&lt;T&gt; &gt;</code></td>
</tr>
</tbody>
</table>
2.2.5 User-Defined Collections

It is also possible to make DOOM treat an arbitrary class as a collection. For this to make sense, it must be possible to represent the state of an instance of the class by an ordered list of values of some uniform type. There are several steps required to use a user-defined collection type:

1. You must define an adapter class for your collection class. This makes it possible to get data into and out of the collection using a uniform interface. Your adapter class must derive from d0om.Collection.Adapter (see d0om/d0om_Collection_Adapter.hpp). It must implement the virtual methods size, collsize, insert_elements, iterate, construct, and destroy.

Note that there are several existing adapter classes which you might be able to use.

- If your collection has an interface compatible with an STL sequence, you can use d0om_STL_Sequence_Adapter. Specifically, it must:
  - Define value_type, which must have a default constructor.
  - Define iterator as at least a forward iterator.
  - Implement clear().
  - Implement size().
  - Implement begin().
  - Implement end().
  - Implement insert (p, n, t), where p is an iterator, n is an integer, and t is an instance of value_type.

- If your collection has an interface compatible with an STL associative container, you can use d0om_STL_Assoc_Adapter. Specifically, it must:
  - Define value_type, which must have a default constructor.
  - Define iterator as at least an input iterator.
  - Implement clear().
  - Implement size().
  - Implement begin().
  - Implement end().
  - Implement insert (p, t), where p is an iterator and t is an instance of value_type.

2. Your collection should define the value_type, giving the type of a collection element.

3. Your collection should also define d0om_collection_adapter as a typedef name for the adapter class. Note that this name must be defined in the collection class itself, and not in a base class (otherwise, it would be impossible to derive an ordinary class from a collection class).
4. In most contexts where you use your collection class, the complete declaration of the adapter class is not required. However, it is required when you compile linkage files for classes which use the collection. For the adapter classes listed above, this is handled automatically. Otherwise, you must arrange this yourself. This can be done by including in the header defining the collection class the construction

```
#define __DOCINT__
#pragma linkage include "adapter-header"
#endif
```

This causes d0cint to emit `#include "adapter-header"` in the generated linkage file.

For an example of this, see mycoll, mycoll_adapter, and myclasses10 in the DOOM tests directory.

If you are want to adapt an existing class without modifying it but are having trouble due to the required typedefs, the `#pragma extendclass` directive may be useful. See Section 9.1 for more information.

### 2.3 DOOM String Class

[Note: The d0_String class is now in the d0_util package.]

The DOOM string class is derived from the ANSI standard string class (see Fig. 3). The DOOM string class exists for various technical reasons: it fixes bugs and omissions in various vendor’s string implementations, and it can lead to much shorter external names. (This has been seen to make a considerable difference in object file sizes.) From the user’s point of view, d0_String provides the same functionality as string. The GNU C++ compiler (v2.7) is known to contain a bug for which the workaround is to include the DOOM string header before any other DOOM header.

The plain C++ string (or basic_string) class can also be saved. Also note that the d0_String class is independent from the rest of the persistency mechanism.
2.4 DØOM Reference Classes

The DØOM reference class d0_Ref<T> functions in many ways like the pointer type T*. In particular, d0_Ref<T> can be dereferenced by the C++ operators * and ->. The class d0_Ref<T> is sometimes called a “smart pointer.” References provide more functionality than standard pointers. DØOM references currently have the following features.

1. Reference counting of dynamic C++ objects.
2. Deferred conversion of dSPACK objects to C++ format.
3. Deferred I/O for database objects.

2.4.1 Reference Counting

A reference count is logically associated to every persistent object on the heap. This is true whether or not an object has been instantiated in C++ format. For efficiency reasons, whenever possible DØOM defers I/O or data conversion until a reference has been dereferenced. References to static and automatic objects do not have reference counts, but such objects can still be pointed to by d0_Ref<T>. Object reference counts interact with DØOM references as follows:

1. Objects created using the new operator get a reference count of zero.
2. When an object is read from external storage, a reference pointing to a non-instantiated C++ object, and having a reference count of one, is returned to the user.
3. The reference count is incremented when a reference is set to point at the object. This normally happens when a reference is initialized, assigned, or copied.
4. When a reference is cleared or destroyed, the reference count associated with the pointed-to object is decremented. If the reference count reaches zero, the object is deleted.

The programmer is not responsible for deleting objects that are managed by references. Because the reference itself takes care of deleting heap objects, memory leaks and dangling references are less likely than with standard pointers. Memory leaks are still possible if several objects containing references point to each other in a loop. In such cases, the programmer must break the loop in at least one place by calling the clear() method of d0_Ref<T>.

It is possible to create a d0_Ref from a C++ pointer without affecting the reference count of the C++ object. This is done with the following construction:

```cpp
X* xptr;
...
d0_Ref<X> xref (xptr, d0_Ref_Base::NOREFCOUNT);
```
This will not affect the reference count of the object pointed to by XPTR, either when the reference is constructed or when it is deleted. This property is copied along with the reference.

2.4.2 d0_ref<T> Methods

The following methods are defined for d0_ref<T>:

- d0_ref() Constructor.
- d0_ref(T*) Constructor.
- d0_ref(d0_ref<U>()) Constructor.
- d0_ref(T*, Norefcount) Constructor that doesn’t alter the reference count.
- T* operator->() Dereference.
- T& operator*() Dereference.
- d0_ref<T>& Assignment.
- operator=(T*) Assignment.
- d0_ref<T>& Test for a non-null reference.
- operator bool() Test for a null reference.
- bool operator!() Clear the pointer and decrement the reference count.
- void clear() Return the dynamic type of the object which this d0_ref references. If possible, do it without creating the object. Whether this is possible or not depends on the I/O backend.
- d0om_type() Clear the pointer and delete the pointed-to object. Throw an exception if the reference count is greater than one.
- void delete_object() bool has_field (const d0_string& fieldname, 
 const d0om_type_class* cls = 0)

Examine the version of cls present in the same place that the object that this d0_ref points to is located. (In the same dsack event, for example.) If cls is defaulted to zero, examine the class of the object that this reference points to. Return true if that version of cls had a field named fieldname. (I.e., return true if the field named was really present in the data being read, rather than being defaulted.)
At present, this only really works with the dpack backend; others will just test the for
fieldname in the current version of the class.
If possible, we do this operation without actually creating the object to which this d0_Ref
points; whether this is possible or not depends
on the I/O backend.

bool is_deferred()
True if the object at which this reference is
pointing has not yet been constructed.

bool is_dereferenceable()
(I.e., not is_null and either not is_unknown
or d0om_Options: :unknown_action has been
set to MAKE_UNKNOWN.)

bool is_null()
Is anything being pointed to?

bool is_unknown()
True if the object at which this reference is
pointing does not have compiled-in type infor-
mation. (See Section 7.)

T* ptr()
Return the corresponding C++ pointer.

T* ptr_only()
Like ptr(), but if the C++ object hasn’t yet
been constructed, just return null.

void purge_object()
Delete the object instance this d0_Ref is
pointing at, but leave the reference valid so
that the object can be recreated from persis-
tent storage if it is dereferenced again. Ex-
ceptions: If the d0_Ref isn’t doing reference
counting, this just clears it. If the d0_Ref is
pointing at an object that wasn’t read from
persistent storage, the d0_Ref is just cleared.
If there’s more than one d0_Ref pointing at
the object, an exception is thrown.

T* release()
Release ownership of the object (similar to
auto_ptr<T>: :release). If the object this
d0_Ref is pointing to is not reference-counted,
just return the pointer to it. Otherwise, if the
reference count is not 1, throw an exception.
Otherwise, clear this reference, reset the refer-
ence count on the object to 0, and return the
object pointer.

int version (const d0om_Type_Class* cls = 0)
Examine the version of cls present in the same place that the object that this d0_Ref points to is located. (In the same DSPACK event, for example.) If cls is defaulted to zero, examine the class of the object that this reference points to. Return the version number of that instance, or 0 if we couldn’t find a version number. For backends that don’t store version information, this will return the current version. If possible, we do this operation without actually creating the object to which this d0_Ref points; whether this is possible or not depends on the I/O backend.

All six relational operators are defined for d0_Ref. A d0_Ref can also be compared for equality with bare pointers.

The class d0_Ref also provides the typedef names pointer (T*), const_pointer (T const *) and element_type (T).

The following global typedefs are provided for convenience:

\[
d0_{\text{Ref\_Any}} \quad d0_{\text{Ref<}}d0_{\text{Object}}
\]

\[
d0_{\text{Const\_Ref\_Any}} \quad d0_{\text{Ref<}}\text{const }d0_{\text{Object}}
\]

The has_field and version methods deserve a little more explanation for the cls argument. DOOM can only handle references (and pointers) to instances of d0_Object. Thus, if one wants to specify an instance to DOOM it must be an instance of d0_Object. But for these methods, one would like to be able to get information about classes that do not derive from d0_Object. That is why the cls argument is present. For example, given the following definitions:

```cpp
struct A {}
struct B :
  public d0_Object
{
  D0_OBJECT_SETUP (B);
  A a;
};

d0_Ref<B> r;
```

Then r->version() will give the version of B in the file from which the object pointed to by r was read. To get the version of A, use r->version (A::d0om_type_static()).

Also, when using has_field, note that DOOM does not consider a class to directly contain fields from base classes. Thus, if in addition to the above definitions you had

```cpp
struct C :
  public B
```
{  
    D0_OBJECT_SETUP (C);
};
d0_Ref<C> rc;

then rc->has_field ("a") will return false, but the construction
rc->has_field ("a", B::d0om_static_class()) will return true.

2.4.3 Restrictions

Classes T pointed to by d0_Ref<T> must directly or indirectly derive from d0_Object,
regardless of whether or not they are intended to be persistent.
Classes pointed to by d0_Ref<T> are allowed to be polymorphic or abstract.

2.4.4 Name-Only References

C++ allows pointers to be declared that point to incompletely defined classes. The
same is true of D0OM references.

class T;
d0_Ref<T> pT;

Such name-only reference declarations are desirable in order to reduce the physical
coupling between modules. Some restrictions apply to name-only references. The
following usages are allowed for name-only references.

1. Declaration
2. Copying
3. clear(), delete_object() and is_null() methods.
The following usages are disallowed for name-only references.

1. Dereferencing.
2. Initialization from a C++ pointer.
3. ptr() method.

2.4.5 Reference Type Conversions

Default pointer conversions are carried out automatically when assigning between
d0_Ref instances. For non-default conversions, you must use an explicit cast. The
syntax is as follows:

D0_REFCAST ((type))(object)      Downcast
D0_REF_UNSAFECAST ((type))(object)  Unsafe cast
D0_REFCAST((const type))(object)  Constant downcast
D0_REF_UNSAFECAST((const type))(object)  Constant unsafe cast

17
D0_REFCAST acts like a dynamic_cast, except that it will generate a fatal error if the type of the object is not valid. D0_REF_UNSAFECAST does not do any checking; it is not recommended for general use.

If you are using a compiler that supports explicit specification of function template arguments (i.e., everyone except Microsoft), you can also use the notations

\[
\begin{align*}
\text{d0\_refcast<<type>>(object)} & \quad \text{Downcast} \\
\text{d0\_ref\_unsafe\_cast<<type>>(object)} & \quad \text{Unsafe cast}
\end{align*}
\]

Here are some examples:

d0\_Ref<myclass> r1 = new myclass;
d0\_Ref\_Any r2 = r1;
d0\_Ref<myclass> r3 = D0\_REFCAST((myclass)) (r2);
d0\_Ref<const myclass> r4 = r1;
d0\_Ref<const myclass> r5 = D0\_REFCAST((const myclass)) (r2);

The above macros are type-safe in the sense that a prohibited conversion will result in a compiler error. Refer to the header file d0\_Ref.hpp for more information about reference type conversions and how to use the above macros.

Note that these macros will not work with type names containing commas. You must define a separate typedef name for those. The old macros D0\_REFCONV, D0\_CONSTR\_REFCONV, D0\_CONST\_REFCAST, and D0\_REF\_CONST\_UNSAFECAST are no longer needed, but are retained for backwards compatibility.

### 2.5 C++ Bare Pointers

C++ bare pointers are allowed in persistent classes. The pointed-to class must derive from d0\_Object. Pointers are allowed mainly so that preexisting classes can more easily be made persistent. For new classes, it is recommended to use the DOOM reference class d0\_Ref<T>, as described in section 2.4.

Whenever an object with C++ pointers is read, all the objects to which it points are also read (no deferred I/O). The user is responsible for deleting these objects when done with them.

Because of the different way in which references and pointers manage memory, pointers and references should not simultaneously be made to point to the same object. DOOM attempts to enforce this prohibition.

As with DOOM references, persistent pointers can be used to point to polymorphic or abstract classes.

There are two functions available to do the equivalent of D0\_Ref::version and D0\_Ref::has\_field for bare pointers:

```cpp
namespace d0om {

    int get\_version (const d0\_Object* o, const d0om\_Type\_Class* cls = 0);

    bool has\_field (const d0\_Object* o,
```
const d0_String& fieldname,
    const d0om_Type_Class* cls = 0);
}

They work just like the d0_Ref methods described in section 2.4.2, except that they
take a pointer to the object as an additional argument. These functions get declared
if you include the header d0_Ref.hpp.

2.6  C++ auto_ptr Class

The C++ auto_ptr class may also be used, subject to the same restrictions as for
bare C++ pointers. In addition, it is an error to write a structure which contains
more than one auto_ptr points at a given object, though there is no checking for
this. (Be careful with using the CD2 auto_ptr class, as it is easy to leave unowned
dangling pointers. The version of auto_ptr actually approved for the standard should
make it harder to run into this.)

2.7  Transient Data in Persistent Classes

Classes are allowed to contain transient data members. Such members are not read
to or written from the persistent store. A class designer can mark a data member
transient using the directive #pragma transient member-names. Here, member-
names is a comma-separated list of the names of the members which you want to be
transient. They are looked up using the scope which is current at the point where the
directive appears; the directive does not have to be lexically inside the class which
it is modifying. A #pragma transient directive should probably be placed inside
a #ifdef __DOCMINT__ construction, to hide it from translators other than d0cint.
(Or use DOOM_TRANSIENT; see section 9.2.) Alternatively, a field may be marked
as transient by including a C++ comment beginning with the string “//!” on the
same line as the field declaration. (This convention was borrowed from ROOT.) This
syntax, however, is deprecated. Also, any data field that is not a recognized DOOM
persistent type is transient by default (but you may get a warning).

Examples:

class foo
{
    public:
        int a;
        int b;  //! foo::b is transient

    struct bar
    {
        int d;
        int e;
    };

19
int f;

#ifdef __D0CINT__
#pragma transient f // foo::f is transient
#endif
;

#ifdef __D0CINT__
#pragma transient foo::a, foo::bar::e
   // foo::a and foo::bar::e are transient.
#endif

The d0_Object interface provides two methods, activate and deactivate, for initializing and deinitializing transient members when they are moved into and out of memory (see section 2.8.3).

Related to #pragma transient is #pragma nowrite, which declares that a member is to be read, but not written. See Section 8.4 for further discussion.

2.8 DØOM Base Class and Inheritance

A persistent class which is to be referred to by a pointer or d0_Ref must inherit, directly or indirectly, from the persistent base class d0_Object. Either single or multiple inheritance may be used. Figure 4 shows an example of persistence via single inheritance.

class A : public d0_Object { ... };
class B : public A { ... };

The classes A and B are both persistent.

If a class is used only as a data member of another class or as the element type of a container, then it need not derive from d0_Object. Example:

class A {};

class B : public d0_Object
{
public:
   A a; // OK
   std::list<A> alist; // OK
   A* aptr; // BAD
   d0_Ref<A> aref; // BAD
   B* bptr; // OK

   D0_OBJECT_SETUP (B);
}
2.8.1 Multiple Inheritance

Figure 5 shows the simplest case of persistence via multiple inheritance.

```cpp
class pA : public A, public d0_Object { ... };
```

Multiple inheritance has been used to define a persistent version `pA` of a non-persistent class `A`. Note that only persistence capable fields of `A` will persist in `pA`.

A more complex example of multiple inheritance is shown in Figure 6.
class pA : public A, virtual public d0_Object { ...};
class pB : public B, virtual public d0_Object { ...};
class C : public pA, public pB { ...};

In this example, class C multiply inherits from two persistent classes pA and pB. The classes pA and pB must use virtual inheritance with respect to d0_Object to ensure that only copy of d0_Object is contained in class C. In general, the following restrictions apply to the use of multiple inheritance.

1. Only one copy of any class may be inherited in a persistent class. Use of virtual inheritance may be necessary to ensure this.

2. Virtual base classes may not contain any persistent data.

2.8.2 Polymorphism

Polymorphism is allowed in the DÖOM object model via the reference class d0_Ref<T> and pointers. References and pointers in persistent classes can point to polymorphic or abstract classes.

2.8.3 Activate and Deactivate

In general, a persistent class designer does not need to be concerned very much with the interface of the class d0_Object. Possible exceptions are the methods
“void activate()” and “void deactivate()” of d0_Object. The activate() method is called whenever a persistent object is instantiated in memory (all persistent fields should be filled in at this point). The deactivate() method is called just before an object is written. activate() is intended to regenerate transient data that is dependent on persistent data within the same object. Note that this task can not be handled by a constructor because the constructor does not have access to the object’s persistent data. deactivate() does the same process in reverse.

A class designer may override activate() or deactivate() if they are needed for nontrivial processing. In that case, activate() and deactivate() should explicitly invoke the activate() and deactivate() methods in any base classes.

Note that deactivate() is declared const, and thus any overriding function must also be declared const. This is a statement of the constraint that deactivate() should not change the state of the object as it appears from the outside. If certain class members do need to be changed, they should probably be declared mutable.

2.9 Class Versions

User-defined classes can be defined with an integer version number. When an instance of the class is read in, you can query it to see with what version it was written, through either the d0_Ref<T>::get_version method or the d0om::get_version function (see sections 2.4.2 and 2.5). If the version number is smaller than the current versions, this can also trigger a user-written conversion on input (see section 8.3.3).

You specify the version of a class to DOOM using the #pragma version directive:

class A {};
#ifdef __DOCINT__
#pragma version A 5;
#endif

The version number may be an expression that evaluates to a constant integer. The directive should probably be within a #ifdef __DOCINT__ construct to hide it from processors other than d0cint. (Or use DOOM_VERSION; see section 9.2.)

The version number is stored in the data file as part of the dictionary information. Thus, it does not take up space in each instance of the class. At present (v00-25-00), only the DSPACE supports storing version numbers.

2.10 How Objects Are Reconstructed

When an object is being read in, it is first initialized using one of its constructors. Next, all persistent fields are filled in. (No class methods are invoked for this.) Next, if the object’s class derives from d0_Object, the activate method is called. Finally, if the object is being stored in an associative container, the object’s copy constructor is used to copy it to its final position.

Normally, the default constructor is used to initialize the object. However, sometimes the default constructor does stuff which is not appropriate for when an object
is being read. For example, if an object has a persistent bare C++ pointer, and the
default constructor initializes it to newly-allocated memory, then that memory would
be leaked when the object gets read in. (Note, however, that this particular problem
would go away if a d0_Ref were used instead of a bare pointer.)

To solve this problem, you can define a constructor which has a signature of

\begin{verbatim}
(const d0_Input_Info*)
\end{verbatim}

If such a definition is present, then that constructor will be used instead of the default constructor to initialize objects which are being
read in. Presently, the pointer which gets passed to the constructor will be null, but
it may be used in the future to provide additional information to the constructor.

If a d0_Input_Info constructor is provided, the default constructor need not be
present.

Note also that this behavior is only applicable for top-level (complete) objects.
For objects contained inside of other objects, the constructor used is determined by
the containing object.

### 2.11 Nested Classes

Nested classes (classes defined within other classes) are allowed in DOOM. Nested
classes can be persistent or contained in other persistent classes. The rules for persist-
tent nested classes are the same as for non-nested classes. Namely, they must derive
from d0_Object and otherwise conform to the DOOM object model. Note that nested
classes or structures must be named; they cannot be left anonymous. Also, if a nested
class derives from d0_Object, it must be public.

### 2.12 Namespaces

Namespaces may be used. A name in a namespace is treated much like a name in
a class scope. The using directive is not fully implemented; you should explicitly
qualify any names you use in a header rather than using a using directive.

### 2.13 Preprocessor Macros

Cint has only a limited implementation of the C preprocessor.

Conditionals on macro definitions (#if defined, #ifdef, #ifndef) should work.
In most cases, simple macros (without parameters) should work as long as the
macro definition is a constant or a type name.

Macros with arguments can be used, but only in certain contexts. They should
work at the start of a statement, or in a position where a function call may appear.
They probably won’t work in other places. Token pasting works, but stringification
does not.

In general, it is a good idea to rely on preprocessor macros as little as possible in
sources which d0cint is supposed to read.
2.14 Template Classes

Template classes are allowed in DOOM. Template classes can be persistent or contained in other persistent classes. The rules for persistent template classes are the same as for non-template classes. Namely, they must derive from d0_object and conform to the DOOM object model. In addition it is necessary to declare to the DOOM preprocessor those instantiations of a template class that are to be made persistent. This is done using the #pragma linkage directive (see Section 5.9):

```cpp
#pragma linkage my_template_class<int>
```

These directives should usually be put inside an #ifdef __DOCINT__ guard to hide them from translators other than doctint. (Or use DOOM_LINKAGE; see section 9.2.) The name given in the directive is looked up in the scope which is current at the point where it occurs.

A template instantiation may also be declared with a pseudocomment with the following format:

```cpp
//! +class my_template_class<int>
```

In this case, the name must be fully qualified, i.e., if it is in a namespace or class scope, this must be given explicitly.

The linkage directive is probably best placed where where the instantiation is used.

Here is an example:

```cpp
/*** tmpl.hpp ***/

template <class T>
struct tmpl
{
    T x;
};

/*** tint.hpp ***/

#include "tmpl.hpp"
#include "d0om/d0_object.hpp"

class tint : public d0_object
{
    public:
        tmpl<int> y;
};
```
#ifdef __DOCINT__
# pragma linkage tmpl<int>
#endif

/*** tfloat.hpp ***/

#include "tmpl.hpp"
#include "d0om/d0_Object.hpp"

class tfloat : public d0_Object
{
 public:
   tmpl<float> y;
};

#ifdef __DOCINT__
# pragma linkage tmpl<float>
#endif

One would then run tint.hpp and tfloat.hpp through d0cint. It is unnecessary to run d0cint on tmpl.hpp here, as that header does not actually define any classes — it only defines the template.

An alternate method for signaling that d0cint should generate linkage information for a template class is provided by the d0om_autolink typedef. This is described in Section 5.9.

It is also possible to use non-type template arguments; however, d0cint’s support for them is incomplete. Numeric types should work ok. The character string types char* and const char* should also work, with the caveat that d0cint will not attempt to evaluate expressions given for such arguments — the expression text is simply copied. This implies that any nested names appearing as a character string template argument should be fully namespace- and class-qualified.

Types other than the above are not really supported; they may work sometimes, but that’s more by chance than by design...

2.15 Translated Classes

Sometimes, one wants to use a class from an external source. This class does not satisfy the requirements of DOOM, and it cannot be changed, but you want to be able to save it. In some cases, this can be accomplished by defining it as a translated class, as described below.
Note that as this mechanism is somewhat complicated to set up, we recommend that it be used mainly to adapt existing external classes. New D0 code should probably be written to use DOOM directly. In addition, the class to be translated can only be used as a member of another class — you can’t have a pointer to it directly. (However, the translated class can have internal pieces which are reached by pointers, as long as these pieces are not directly referenced by DOOM objects.)

Setting up a translated class actually requires three classes. The first is the class you want to adapt, called the target class. Given the target class, you should write another class which contains all the persistent state of the target class and which satisfies the requirements of DOOM. This is called the dummy class. Finally, you need to write the translator class, which knows how to convert between the target class and the dummy class. The translator class should derive from the abstract class d0om_Class_Translator. Here is a list of methods which it should implement.

- **void** makedum_fromtarg (**const** void* **targ**) const
  
  Given a pointer to an instance of the target class, create an instance of the dummy class containing the same information.

- **void** deldum (**void** **dum**) const
  
  Delete an instance of the dummy class (which was created by the method makedum_fromtarg).

- **void** makedum_empty () const
  
  Make an empty instance of the dummy class.

- **void** copydum_totarg (**void** * **targ**, **void** * **dum**) const
  
  Given a pointer to an instance of the dummy class (created by makedum_empty) and an instance of the target class, copy the dummy instance to the target instance. Then delete the dummy instance.

- **void** construct (**void** * **targ**) const
  
  Construct an instance of the target class.

- **void** destroy (**void** * **targ**) const
  
  Destroy an instance of the target class.

- **void** zero (**void** * **targ**) const
  
  Clear an instance of the target class.

- **int** size () const
  
  Return the size of an instance of the target class, in bytes.

- **int** align () const
  
  Return the required alignment of an instance of the target class, in bytes.

The translator class is linked to the dummy class by putting a typedef declaration of d0om_class_translator in the dummy class.
There is also simplified translator interface that can be used in many circumstances. To use it, both the target and dummy classes must have default constructors, and it should be appropriate to align instances of the target class at eight-byte boundaries. In that case, you can instead derive from the template class d0om::Translator_Helper<Target, Dummy>, where Target and Dummy are the target and dummy classes, respectively. (This class in turn derives from d0om::Class_Translator). The d0om::Translator_Helper class has only three pure methods that must be supplied:

- **void zero_target (Target& targ) const**
  Clear out the target instance *targ.*

- **void target_to_dummy (const Target& targ, Dummy& dum) const**
  Convert *targ* to *dum.*

- **void dummy_to_target (const Dummy& dum, Target& targ) const**
  Convert *dum* to *targ.*

How this all gets organized in the header files is a bit tricky. I'll go through an example, showing one way which seems to work.

Suppose you want to adapt a class named *C*. The header file for this class is in *otherstuff/C.hpp*. The package in which you're including the translator is called *mystuff*.

First, create the dummy class. That can be defined in the file *mystuff/C_dum.hpp*, and look something like this:

class C_Translator;

#ifdef __DOCINT__
class C
#else
class C_dum
#endif
{
public:
  typedef C_Translator d0om_class_translator;

  // Define the persistent data here.
  ...
};

#ifdef DOOM_LINKAGE_FILE
  typedef C_dum C;
#endif

28
#ifdef __DOCINT__
#pragma linkageinclude "mystuff/C_Translator.hpp"
#endif

When this header is included in normal C++ code (such as from the translator class), it defines the dummy class C_dum. However, when run through d0cint, it appears to define the class C. This is the definition of class C, as far as d0cint is concerned. The linkage file which d0cint emits will then contain references directly to the class C. That’s the reason for the line typedef C_dum C. This line is visible only when the linkage file is being compiled. You tell d0cint that this is a translated class with the d0om_class_translator typedef; the target of the typedef is the translator class. In order for the generated linkage file to compile, the full declaration of the translator class must be present. But it may not be desirable to couple C_dum.hpp to C_Translator.hpp. This can be avoided by using the linkageinclude directive, as in the example. The directive #pragma linkageinclude text causes d0cint to emit #include text in the generated linkage file.

This header defining the dummy class should be run through d0cint, generating a linkage file and a reference header.

Next, write the translator class. In this example, it would be called C_Translator and be defined in C_Translator.hpp. Finally, you may need a wrapper for the target class. This can be called mystuff/C.hpp, and might look something like

// If d0cint will read otherstuff/C.hpp, you can just include it here.
#include "otherstuff/C.hpp"

#include "mystuff/C_dum_ref.hpp"
#endif

The linkageinclude here ensures that any persistent class using this header will automatically get the definition for the dummy class. If d0cint will not read otherstuff/C.hpp, you can instead do the following:

#ifndef __DOCINT__
    // A dummy definition of C, that d0cint can parse.
    ...
#else
    #include "otherstuff/C.hpp"
#endif

Then, to use the translated class, you include mystuff/C.hpp from your classes, rather than otherstuff/C.hpp. Note that, at present, this mechanism is available only if you are using the DSPACK backend.
2.16 ZOOM and CLHEP Classes

The following classes from Zoom and CLHEP may also be used:

- **LinearAlgebra**
  - MatrixC
  - MatrixD
  - ColumnVector
  - RowVector

- **PhysicsVectors**
  - SpaceVector
  - UnitVector
  - LorentzVector
  - PlaneVector
  - AxisAngle
  - EulerAngles
  - Rotation
  - RotationX
  - RotationY
  - RotationZ
  - LorentzTransformation
  - LorentzBoost
  - LorentzBoostX
  - LorentzBoostY
  - LorentzBoostZ

- **CLHEP/Vectors**
  - Hep3Vector
  - HepLorentzVector
  - HepRotation
  - HepLorentzRotation

- **CLHEP/Matrix**
  - HepMatrix
  - HepDiagMatrix
- HepSymMatrix
- HepVector

The d0om_zm package must be accessible for this to work. If you use any of these classes in a persistent class, you should link with the additional library -ld0om_zm.

The names from the FixedTypes header may also be used.

Note that some caution is needed with the vector classes from CLHEP, as there are different classes with the same names present in the Zoom PhysicsVectors package.

2.17 Reserved Member Names

Member names beginning with two underscores are reserved. The following reserved names are presently defined:

- __baseN — DOOM implements base classes by treating them like additional member fields (this is the origin of the restriction against having data in virtual bases). These members are given names of the form __baseN, where N is an integer. Members with names of this form should never be used in the input to d0cint.

- __offsetN — If d0cint sees a member name of this form, it interprets the member to be fixed at offset N within the C++ object. This can be useful in making external classes work with DOOM, where you want to “overlay” an external definition with one which works with DOOM (and has the same layout). See thebitset and complex classes for examples of this.

- __packed — Used to store any packed fields in the class. See Section 2.18.

2.18 Packed Fields

Sometimes, one wants to pack data tighter than it would naturally be stored. You can tell DOOM to attempt this with the #pragma pack directive. Note that how this is implemented depends on the specific I/O backend — at present, the DSPACK backend is the only one that handles packed data. (But it should be ok to specify #pragma pack directives even if you’re using a backend that doesn’t support them — they will just be ignored.) Also note that saving and restoring packed fields is likely to be much slower than ones that haven’t been packed.

Only members of boolean or numeric type or collections of them may be packed.

The syntax of the packing directive is

    #pragma pack (packspec) member-names

Here, packspec describes the sort of packing to do and member-names is a comma-separated list of the member names to be packed. They are looked up using the scope which is current at the point where the directive appears; the directive does not have to be lexically inside the class which it is modifying. A #pragma transient directive
should probably be placed inside a _ifdef __D0CINT__ construction, to hide it from
translators other than d0cint. (Or use DOOM_TRANSIENT; see section 9.2.)

The packing specification packspec consists of a comma-separated list of “key-
word=value” pairs. The set of keywords accepted depends on the data type of the
member, as listed below. All types, however, accept the nbits keyword, giving the
requested number of bits to be used to store this member. This must be in the range
1–32.

- **bool** — Boolean fields have only the nbits keyword.
- **Integer types** — Besides the nbits keyword, integer types may also have the
  keywords lo and hi. These give the (inclusive) range of values allowed for this
  member. If either lo or hi is specified, both of them must be. If a range is
  specified, then the nbits keyword may be omitted. In that case, the number of
  bits will be chosen to be just large enough to hold the requested range.
- **Floating point types** — Besides the nbits keyword, the following keywords may
  be specified:
  - **scale** — If provided (and nonzero), the number being stored will be di-
    vided by this value before being stored. This allows one to scale numbers
    into the range allowed for fixed-point representations.
  - **signed** — If this keyword is set to “0”, then a sign bit will not be stored:
    i.e., all numbers to be stored must be nonnegative. This defaults to “1”.
  - **nmantissa** — The number of bits to use for the mantissa of the represen-
    tation, excluding the sign bit (if any). All remaining bits left over from
    nbits after taking out the nmantissa bits and the optional sign bit are
    used for the exponent. If there are no more bits left (or if nmantissa
    wasn’t specified), then a fixed-point representation is used. In the fixed-
    point case, the numbers being stored must be in the range (−1, 1) (or [0, 1)
    if no sign bit is being stored).

Here are some examples:

class Pack_Test
{
public:
    int a;
    int b;
    unsigned int c;
    bool d;
    float f;
    float g;

#ifdef __D0CINT__
# pragma pack (nbits=4) a;
# pragma pack (lo=10, hi=14) b;
# pragma pack (nbits=12, lo=0, hi=14) c;
# pragma pack (nbits=1) d;
# pragma pack (nbits=10, scale=20.5) f;
# pragma pack (nbits=10, scale=20.5, nmantissa=5) g;
#else
};

A packing directive may also be used for arrays and collections of packable types:

class Pack_Test
{
public:
    int aa[3];
    unsigned int cc[3];
    bool dd[3];
    float ff[3];

    std::list<int> l;
    std::vector<int> v;

#endif
#endif
#else
#pragma pack (nbits=4) aa;
#pragma pack (nbits=12) cc;
#pragma pack (nbits=1) dd;
#pragma pack (nbits=10) ff;

#pragma pack (nbits=5) l;
#pragma pack (nbits=8) v;
#endif
};

2.18.1 DSPACK Implementation of Packed Fields

Here are some notes on the implementation of packing in the DSPACK backend.

The fields stored by DSPACK are always at least 32 bits wide. If a class has packed members, DOOM implements it on top of DSPACK by declaring a dummy field "_packed" to DSPACK and packing the data into there. DOOM maintains the metadata describing the format of the packed data itself, outside of DSPACK. (The information is stored as part of the comment string for the _packed field.) An array of N members is packed just like it was N separate members, and packed collections are stored like collections of integers.

This implies that a class instance must always take up an even multiple of 32 bits when stored, even if its contents could be packed to a smaller size.

In addition, the current implementation has a restriction that packed fields cannot cross a 32-bit boundary. This can cause DOOM to insert additional padding to achieve
this. This limitation may be removed in the future.

Packing directives may be freely changed (or added or removed) without affecting the ability to read old data.

3 DØOM I/O Interface

DØOM I/O proceeds though an abstract interface that is independent of the underlying I/O mechanism. The underlying I/O mechanism can be changed without requiring any modification of the I/O interface.

3.1 Class d0Stream

The main I/O interface class is an abstract class called d0Stream. The class d0Stream is intended to look and feel like a sequential or random access disk file, regardless of the underlying I/O implementation. The underlying I/O could in principle be to a single file, a sequential file list, federated files, a virtual stream, a database, shared memory, a network connection, or something else. Different concrete subclasses of d0Stream correspond to different underlying I/O mechanisms (see Fig. 7). In addition to concrete subclasses, class d0Stream has an abstract subclass d0StreamDB, which extends the d0Stream interface in ways that are appropriate for databases. Class d0StreamDB has its own concrete subclasses corresponding to different physical databases. Classes d0Stream and d0StreamDB are in the cvs module named d0stream.

3.1.1 Methods of d0Stream

The following methods are available in d0Stream.

```cpp
int close() // Close a stream.
d0_Ref<Any> read(const d0Key* key=NULL,
const std::string event_key="") // Read an event.
void write(const d0_Object& object,
const std::string event_key="") // Write an event.
bool bind(const d0_Object& object,
d0_Key& key) // Associate a key with an object.
void unbind(const d0Key& key) // Delete the specified key.
const d0Key* make_key(const char* key_string) // Create a key and initialize it with a character string.
d0_List<d0Key> keys() const // Return a list of all known d0Key's.
d0_List<std::string> event_keys() const // Return a list of all known event keys.
```

34
int lookup(std::string event_key)

void seek(size_t offset)

int tell()

Position the stream at the given event key.
Seek to the specified offset.
Return the current offset.

Note that there is no open method. Objects of type d0Stream are returned already opened when the are created.

3.1.2 Random Access and Keys

Methods of the d0Stream interface make use of two different kinds of keys. Methods, read, bind, and unbind take either a reference or a pointer to a d0Key. Methods read, write, and lookup take a string argument which is interpreted as an event key. Either kind of key can be used for keyed random access in certain situations. Both kinds of keyed access work similarly. A key is associated with an event, using either the bind method (for d0Key's) or the event key argument of write. Keyed access is then accomplished using arguments of read (for either kind of key), or the lookup method (for event keys). Depending on the underlying I/O mechanism, the two kinds of keys may be implemented differently, or not at all. The following statements apply to the two kinds of keys.

1. For event oriented I/O mechanisms, event keys point to entire events and d0Key's point to individual objects within an event.

2. Database I/O mechanisms implement both event keys and d0Key's using a single underlying key mechanism.

3. Event keys are always represented as strings. d0Key's are in principle polymorphic, although at present the only concrete implementation of class d0Key uses a single string its sole datum.

4. At most one event key can be associated with an object. With d0Key's, many keys can be associated with the same object by calling bind repeatedly.

5. The dSPACK I/O mechanism (class d0StreamDSPPACK) does not implement any random access mechanism that is accessible through the d0Stream interface.

6. The EVPACK I/O mechanism (class d0StreamEVPACK) implements keyed random access using event keys and via offset (seek/tell).

7. Both the dSPACK and EVPACK I/O mechanisms interpret the d0Key argument of method read as the name of a class within the current event (bind/unbind has no effect).
Figure 7: Inheritance diagram for d0Stream.
3.1.3 Random Access Recommendations

1. Use event keys in preference to d0Key’s unless you need a feature that is only available with d0Key’s (i.e. multiple keys per object or non-string keys). Event keys are implemented for more I/O mechanisms than d0Key’s, and their usage is more consistent between I/O mechanisms.

2. Use the EVPACK I/O mechanism for simple random access. Use a database only if you need database specific features, such as queries. EVPACK will give you better performance and better transportability.

3.1.4 Methods of d0StreamDB

The following methods are available in d0streamDB.

void open_transaction(bool readonly)  Open a transaction.
void commit_transaction()  Commit a transaction.
void abort_transaction()  Abort a transaction.
d0_List<d0_Ref_Any> query(const d0_String& classname,
const d0_String& condition,
const d0_String& tables="",
const d0_String& fields="")
Query database.

The above methods are designed to support transaction and query operations with a real underlying database, such as Oracle. The query method has the following four arguments, of which the last two are optional.

1. Classname. This is the C++ name of a concrete C++ class. The returned d0_Ref_Any pointers can be downcast (using D0_REFCAST) to the specified class, or a base class of the specified class, but not to a class that is derived from the specified class.

2. Condition. This is in general an arbitrary SQL select statement clause, such a where or order by clause.

3. Tables. This argument contains a comma separated list of tables (not including the table corresponding to the classname argument) to add to the from clause of the generated select statement. A non-null tables argument would typically be required for queries containing join operations, or in general any time table-qualified fields appear in the condition argument.

4. Fields. This argument contains a comma separated list of additional fields to fetch in this query. Fields can be specified in the forms “column” for single-table queries, or “table.column” for multitable queries. The fields and tables arguments have no effect on the returned list of pointers, but only on whether the query generates an error or not.
Name Mangling Issues in Queries. In general, the `condition`, `tables`, and `fields` arguments contain raw SQL that is edited directly into an SQL `select` statement. Therefore, table and column names appearing in these arguments should correspond to database table and column names, which are not in general the same as the corresponding C++ class and field names.

All three of the SQL arguments allow C++ names to be used instead of database names by enclosing them in `$(...)`. The string `$(class.field)` appearing in any of these arguments is converted into a string of the form `table.column`. The parsing of `$(...)` expressions is governed by the following rules.

1. Simple scalar fields of C++ classes are specified in the form `$(class.field)`.

2. Array fields are specified using normal C++ notation: `$(class.field[n])`. For this to work, the database schema must be such that the array is not broken out as a separate table. In general, this will be true for “short” arrays.

3. Fields of contained classes are specified in the form `$(class.subclass.field)`. In this case, `class` is translated into the database table, and `subclass.field` is translated into the database column. For this to work, the database schema must be such that contained class is not broken out as a separate table. This should usually be true.

4. Template class names, such as containers, are allowed. They are specified in normal C++ notation.

5. Base classes are treated like contained classes. Field names for base classes are `_base1, _base2`, etc., where the number of the base class corresponds to their order in the class definition. A typical C++ field expression would be `$(class._base1.field)`.

6. The `class` can be omitted in single table queries. The following forms are permitted: `$(field), $(.field), $(.subclass.field)`. The form `$(subclass.field)` (without a leading period) is not allowed, because in this case `subclass` would be interpreted as a class name.

7. Mixed forms, where the class is specified in C++ format, but the field is specified in database format are allowed, for example `$(class.)objid`. This syntax is useful to specify database columns that do not correspond to any C++ class field (i.e. metafields).

8. Some C++ class fields, such as containers and large arrays are broken out as separate database tables. The `$(...)` notation does not provide a way to reach into such auxiliary tables. It may still be possible to reach into such tables by using a join operation which matches the container field of the parent class with the object id field of the container class.
3.2 Factory Class d0StreamFactory

A factory class d0StreamFactory exists to provide users with instances of subclasses of d0Stream. The factory class serves to shield end users from having to directly instantiate d0Stream's concrete subclasses. The factory class also reduces the amount of compile-time and link-time coupling between user code and the d0Stream subclasses. In particular, d0Stream does not have the D0OPEN disease of having link time coupling to every I/O method in the library. Users must explicitly specify linking of d0Stream subclasses that they want in a program.

The class d0StreamFactory is a singleton [3]. It has two methods of interest to users:

```cpp
    static d0StreamFactory* locateStreamFactory ()
    d0Stream* make_d0Stream (const d0StreamName& name,
                const char* streamType = "",
                int mode = ios::in,
                const string& = "")
```

The method locateStreamFactory returns a pointer to the factory singleton. The method make_d0Stream creates an instance of an open d0Stream subclass. The argument streamType is a character string that specifies which type of subclass to create (use "DSPACK" for d0StreamDSPACK, "EVPACK" for d0StreamEVPACK, "ORACLE" for d0StreamORACLE_1, or "CORBA" for d0StreamCORBA_1). The argument streamType may be empty or null when opening files for reading. In that case, d0StreamFactory tries to figure out which type of d0Stream subclass to instantiate. The argument "name" specifies the name of a physical stream (e.g., a filename). The name can be specified as an ordinary C++ double-quoted string. The argument "mode" determines how the specified d0Stream is to be opened. Mode can take the values ios::in (read), ios::out (write), or ios::app (append) defined in the standard header iosstream. The final string argument is not interpreted by d0StreamFactory, but is passed to the create static method of the concrete d0Stream subclass. It typically consists of a sequence of name=value pairs. The interpretation of this string is up to the I/O mechanism. Presently, this is only used by EVPACK; it recognizes a compression_level argument.

Note that d0StreamFactory::make_d0Stream will return null if the code to implement the requested stream type has not been linked into the program. Here is an example of the use of d0StreamFactory and d0Stream.

```cpp
    // Get pointer to factory.
    d0StreamFactory* factory = d0StreamFactory::locateStreamFactory();

    // Create an instance of d0Stream.
    d0Stream* dsin = factory->make_d0Stream("myfile.ds",
                                           "DSPACK", ios::in);
```

39
if (!dsin) {
    cerr << "Can't open input file\n";
    exit (1);
}

// Read event.

d0_Ref<Event> revent = D0_REFCAST((Event))(dsin->read("Event"));

3.3 Output Filters

When writing, you can supply an output filter to control which objects get output. Such a filter is an instance of a class which derives from d0_Output_Filter_Base. See the header file for the definition of the interface; essentially, it provides a method which takes a pointer to an object as an argument and returns a flag saying whether or not that object should be written.

When an object is vetoed by this mechanism, pointers from it are not followed. Thus, vetoing an object implicitly vetoes all other objects which can only be reached via that object. References to vetoed objects are set to null.

To install an output filter, call d0Stream::set_output_filter, passing to it a pointer to an output filter instance. This object should have been allocated off the heap with new. The stream will take ownership of the filter; it will get deleted automatically along with the stream (or the next time the output filter is changed). To remove the output filter, call set_output_filter with a null pointer. The current output filter may be retrieved with output_filter.

There is one concrete output filter implementation available in the library, named d0_Output_Filter. It has the ability to either select or veto individual objects and also to select or veto all objects of a given class. See the header file for more information.

3.4 Memory buffers

EVPACK format data may also be read from and written to memory buffers. This is useful for applications which want to send event data over the network.

3.4.1 Output

Output to memory buffers is done using the class d0StreamEVPACK_Buffered_Output (in d0am_ds). Here is its class definition:

class d0StreamEVPACK_Buffered_Output
    : public d0StreamDSPACK_Base
    
    //
    // Purpose: Evpack stream for writing using
// an arbitrary hook function.
//
{ public:
  // Constructor, destructor.
  // OPTARG is additional arguments to pass to evpack.
  d0StreamEVPACK_Buffered_Output (const std::string& optarg = "");
  ~d0StreamEVPACK_Buffered_Output () {} 

  // Write object.
  virtual void write (const d0_Object &object,
                      const std::string& event_key);

  // Supply this in a derived class.
  // It will be called for every evpack record written.
  virtual std::streamsize writebuf (const char* data,
                                     std::streamsize n = 0); 
};

This class supports the d0Stream interface. However, it cannot be constructed through the d0Stream factory; you must explicitly create the objects. The usual write method will write out a tree of objects.

For each EVPACK record generated, the writebuf method will be called. This is a pure virtual function in d0StreamEVPACK_Buffered_Output, so you should derive from that class and supply a definition for this method. The data will be in the buffer described by the pointer data and the size n. Note that the buffer will not remain valid after writebuf returns, so you should arrange to copy the data somehow.

An example of the use of this class is in one of the d0om_ds test programs, d0om_ds/tests/evpack/twrite_evpack_buf.cpp.

3.4.2 Input

Input to memory buffers is done using the class d0StreamEVPACK_Buffered_Input (in d0om_ds). Here is its class definition:

class d0StreamEVPACK_Buffered_Input
  : public d0StreamDSPACK_Base
  //
  // Purpose: Evpack stream reading from a memory buffer.
  //
  { public:
    // Constructor, destructor.
    // OPTARG is additional arguments to pass to evpack.
    d0StreamEVPACK_Buffered_Input (const std::string& optarg = "");


-d0StreamEVPACK_Buffered_Input () {}  

  // Set the buffer for further input to the chunk of  
  // memory described by DATA and LENGTH.  
  // Use (0, 0) to clear the buffer.  
  // If an attempt is made to read past the end of the buffer,  
  // evpack will behave as if EOF was hit.  
  void set_buffer (void* data, int length);  
};

This class supports the d0Stream interface, including the usual read method. However, it cannot be constructed through the d0Stream factory; one must explicitly create the objects. In addition, random access will not work.

Instead of reading from a file, this stream class reads from a memory buffer, which is supplied via the set_buffer method. The arguments to set_buffer are the address of the buffer and its length. If the end of the buffer is reached, attempts to read from the stream will behave as if EOF was hit.

The method set_buffer may be called as many times as desired, in order to declare a new buffer to a stream. The old buffer is forgotten. To clear the stream’s pointer to the buffer (so that the buffer may be deleted), do set_buffer (0, 0).

An example of the use of this class is in one of the d0om_ds test programs, d0om_ds/tests/evpack/tread_evpack_5.cpp.

3.4.3 Embedded Dictionary Records

The usual organization of a DSPACK file consists of a dictionary record at the start of a file, then some number of data records, and a final dictionary record at the end of the file. In order to be able to interpret the data records, the proper dictionary record must have been read first.

This organization works fine when data is being read from a file. However, it is inconvenient if events are being sent over the network, especially if they are being accumulated from several sources (as in the case of events being received from level 3). Therefore, EVPACK has an option to embed the ds-pack dictionary information within each EVPACK record. (This will, of course, increase the size of the data being written.) To enable this, add the string “embed_defs” to the optarg parameter used when creating an EVPACK output stream.

On input, embedded DSPACK dictionary records are handled automatically. Because it is relatively expensive to process a dictionary record, such a record is read only if it appears to be different from the previously read dictionary record. (This determination is made by using a MD5 checksum of the dictionary record.)

4 Using DØOM

A DØOM program should do the following things.
1. System initialization.

```cpp
    call d0om_init("test");
```

(Declared in d0om/d0om_init.hpp.) The main purpose of this call is to initialize the DOOM type system. The interpretation of the single character string argument is I/O mechanism specific. In the case of DSPACK programs, the argument is passed to the DSPACK initialization routine dsinit, which uses it to identify the client to the server.

2. Get an instance of class d0stream using the stream factory class (see sec. 3.2).

```cpp
    d0StreamFactory* factory =
       d0StreamFactory::locateStreamFactory();
    d0Stream* dsin = factory->make_d0Stream("myfile.ds", "DSPACK",
                                             ios::in);
    if (!dsin) {
       cerr << "Can't open input file:\n";
       exit (1);
    }
```

The instance of d0Stream is returned already opened.

3. Call I/O methods of d0Stream, such as read, write and bind (see sec. 3.1).

4. Call method close and delete the instance of d0Stream.

### 4.1 How to Make a Class Persistent

In general, a programmer must do three things to make a class persistent.

The first step is to make the header file for the class conform with the persistent object model outlined in section 1.1. This means inheriting from d0_Object or another persistent class, and ensuring that persistent data fields are one of the allowed types. The class must also have a default constructor (or a d0_Input_Info constructor, see Sec. 2.10).

The second step is to include the following macro in the body of the class declaration:

```cpp
    D0_OBJECT_SETUP(myclass);
```

The third step in making a persistent class is to run the DOOM preprocessor d0cint. The command to run d0cint is as follows:

```bash
    d0cint myclass_lnk.cc -Iinclude myclass.hpp
```
In the above example, `myclass.hpp` is the input header file and `myclass_lnk.cc` is an output file. The programmer should compile and link the file `myclass_lnk.cc` into his program. The include path for the `d0cint` command should be the same as would be used in a normal compilation. Additional `-I` or `-D` switches may be specified as needed. (A makefile scrap is provided to perform this step for you when you build a library with SRT. See Section 5.8.)

A persistent class can contain both persistent and transient fields. To make a field transient, use the `#pragma transient` directive (see Section 2.7). A data element that is not one of the allowed persistent data types is transient by default. In the latter case, `d0cint` will issue a warning message.

When `d0cint` reads a header, it defines the preprocessor symbols `__CINT__` and `__DOCINT__` in order to identify itself. Thus, if a header contains constructs which `d0cint` is not understanding, they can be enclosed in an `#ifndef __CINT__` or `#ifndef __DOCINT__` to keep `d0cint` from trying to interpret them. (The practical distinction between these symbols is that `__CINT__` is also defined by `rootcint`, while `__DOCINT__` is not.

### 4.2 Reference Headers

One must link into an application the linkage (_lnk) object for every class which is to be used. Since there are normally no external references to the linkage object, this can be problematic if the object gets placed in a library.

Reference headers offer one solution to this. In addition, they provide a mechanism of ensuring that all modules of the application were compiled with compatible definitions for class layouts.

The idea is this. For each class which `d0cint` defines in a _lnk file, it also creates a global symbol definition of the form `d0omhash_classname_hashcode`, where `hashcode` is a 8-character string which depends on the definition of the persistent fields of the class. If you supply the switch `'-ref ref.h'` to `d0cint`, it will write to `ref.h` a C++ header containing external references to those global symbols. This reference header can then be included by the header defining the class. (It should probably be enclosed in a `#ifndef __CINT__` to prevent `d0cint` from trying to read it before it is created.) This should ensure that the linkage object is loaded from a library when it is needed. In addition, if you try to link together objects which were compiled with different versions of the class, you'll get undefined symbols at link-time.

As of v00-17-00, DOOM can automatically make some of these references. For a given class A defined in A.hpp, its linkage file will contain references to the linkage files for all classes which A depends on. Thus, if you have a class which is used only by reference from another class, you don’t need to include its reference header.

### 4.3 d0cint Command Reference

This section summarizes the syntax for the `d0cint` command. Note that in most cases, it should not be necessary to run `d0cint` directly. It should, instead, be run through `d0om_linkage.mk` (see Section 5.8).
Command format:

- **d0cint** *output-file* *options* *input-headers*

The input to d0cint is one or more C++ headers, named in *input-headers*. The output is a C++ source file, named by *output-file*.

If any argument starts with ‘@’, the remainder of the argument should be a file name. The contents of that file are then inserted into the argument list.

The recognized options are listed below. (All options recognized by cint are recognized by d0cint, but only those believed to be useful for d0cint are listed below.)

- **-I** *directory* Add an additional directory to the include path. Directories are searched in the order in which they are specified. For each include directory *directory*, the additional directories *directory/CINT/d0cintinc* and *directory/d0om_zm/d0cintinc* are also added to at the front of the include path (provided that they exist).

- **-D** *macro* Define a macro for the preprocessor. Only macro definitions without a parameter are likely to work well. (I.e., use **-DFOO**, not **-DFOO=bar**.)

- **-t** Trace files included by cint.

- **-T** Echo the input read by cint to standard output, along with additional internal cint debugging information. This can be useful for localizing parsing problems with template or macro definitions. (Note that this is raw output from cint’s reader, and may contain some artifacts due to the details of how cint parses its input. In particular, cint sometimes backs up in the input stream; this can cause some text to be echoed twice.)

- **-v** Dump out the arguments internally passed to the cint main entry point.

- **-q** Suppress the messages listing which classes d0cint generated linkage information for.

- **-ref** *filename* Write a reference header to *filename*. See Section 4.2 for more information.

- **-dep** *filename* Write dependency information to *filename*. This contains the dependencies which the linkage source file has on the headers.

### 4.4 Predefined Macros

When d0cint runs, it defines the following macros to be the values of the corresponding environment variables (without the leading underscores):

- **__SRT_ARCH**

- **__SRT_CXX**
• __SRT_QUAL
• __BFARCH

The macros __DOCINT__ and __CINT__ are also defined.

4.5 Environment Variables For Debugging

There are several environment variables which DOOM examines to control whether to make debugging dumps.

• DOOM_DUMP_DICTIONARY: If this environment variable is defined, DOOM will dump (to stdout) a description of the types that it knows about at the end of the initialization stage.

• DOOM_DS_DUMP_MAPTABLE: If this environment variable is defined, DOOM will dump (to stdout) the internal details of the mappings it builds between DSPACK and C++.

4.6 Functions for Debugging

The following two functions may be useful for tracking down memory leaks involving objects read from DSPACK. Both of these functions are defined in the header d0oom_ds/debug.hpp.

• d0oom_DS::list_objects (std::ostream& os, bool mask_ptr = false) — Dump to os a list of all dspack objects which still have live references. The information printed for each object includes the address (if it has been created), type name, file offset, and dataset index. If mask_ptr is true, then the pointer and file offset fields will be suppressed in the output (this is for regression testing).

• d0oom_DS::summarize_objects (std::ostream& os) — This is similar, but it prints only one line per object type, giving the number of objects with live references of each type.

5 How to Compile and Link a DOOM Program

This section contains some practical instructions on how to get access to DOOM.

5.1 Requirements

The examples in this section assume that the following products are available locally: ups, SoftRedTools, and d0cvs. If d0cvs is unavailable, vanilla cvs should work in most cases. The only d0cvs specific command used in this section is “lscvs.” The examples shown here are known to work on d0chb. The same procedures should work
at remote unix computers. It is not necessary to be local to the cvs repository to use
cvs commands.

DOOM is presently known to work with KCC 3.4g, gcc 2.95, and SGI CC 7.3 on
Irix 6.5, KCC 3.4g, and gcc 2.95 on Linux, and KCC 3.4g on Digital Unix 4.0d. Most
packages should also work on NT with the Microsoft compiler.

5.2 Setups

In general, before compiling or linking a program that uses d0library code, including
DOOM, several setups may be necessary. The most basic setup, which gives access
to released code, and to the SoftRelTools utilities is:

setup D0RunII test

This setup defines the environment variables BFRoot, BFCURRENT, BFDIST, and
BFARCH. To gain access to the cvs repository, use the following setup command:

setup d0cvs

This setup defines the environment variables CVS_DIR, D0CVS_DIR, and CVS_ROOT. It
should also set up the C++ compilers. (If you want to change the C++ compiler
you’re using, you’ll need to change the definition of BFARCH.) For more information
about the D0 cvs and SoftRelTools environments, refer to the D0 code management
web page [4].

5.3 CVS Libraries

Use the d0cvs command “1scvs” to see a list of currently defined cvs modules. The
cvs modules relevant to the DOOM system are shown in Table 7. Package DSPACK
contains the distribution from CERN, slightly modified to build under SRT. CINT
contains the cint C++ interpreter from HP Japan, with numerous local modifications.
d0_util contains a number of utility classes used by DOOM. d0om is the core portion
of DOOM, and d0ostream is the abstract part of the stream code. d0om_ds is the
DOOM-DSPACK interface. The Oracle and Corba interfaces are in d0omORACLE and
d0omCORBA, respectively.

5.4 DOOM Source Code

Already released DOOM source code can be found in the SoftRelTools packages area.
The root directory for DOOM source code is

$BFDIST/packages/d0om/<package-version>.
Table 7: DOOM-related cvs modules.

<table>
<thead>
<tr>
<th>CVS module</th>
<th>Libraries</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>d0omORACLE</td>
<td>-ld0omORACLE</td>
<td>DOOM Oracle interface.</td>
</tr>
<tr>
<td>d0omCORBA</td>
<td>-ld0omCORBA</td>
<td>DOOM Corba interface.</td>
</tr>
<tr>
<td>d0om_zm</td>
<td>-ld0om_zm</td>
<td>Adapters for Zoom classes.</td>
</tr>
<tr>
<td>d0om_ds</td>
<td>-ld0om_ds,-1stream_ds</td>
<td>DOOM DSPACK interface.</td>
</tr>
<tr>
<td>dostream</td>
<td>-1stream</td>
<td>Stream interface code.</td>
</tr>
<tr>
<td>evpack</td>
<td>-evpack</td>
<td>EVPACK package.</td>
</tr>
<tr>
<td>d0om</td>
<td>-ldoom</td>
<td>Basic DOOM code.</td>
</tr>
<tr>
<td>DSPACK</td>
<td>-1dspack</td>
<td>DSPACK package.</td>
</tr>
<tr>
<td>CINT</td>
<td>-lcint</td>
<td>CINT C++ interpreter.</td>
</tr>
<tr>
<td>d0_util</td>
<td>-ld0_util</td>
<td>Utility classes.</td>
</tr>
</tbody>
</table>

5.5 Releases

Already compiled DOOM C++ libraries and the d0cint executable can be found in the SoftRefTools releases area. Some significant directories in the releases area are as follows:

$BFDIST/releases/<release-version> Release root
$BFDIST/releases/<release-version>/bin/$BFRAC Bin executables
$BFDIST/releases/<release-version>/lib/$BFRAC Link libraries
$BFDIST/releases/<release-version>/include Include path
$BFDIST/releases/<release-version>/include/d0om DOOM include files
$BFDIST/releases/<release-version>/d0om Link to DOOM package
$BFDIST/releases/<release-version>/DSPACK Link to DSPACK package

The release version can be a tag, such as “current” or “test”, or a version number. The include path for compilers and d0cint should be specified as -I$BFDIST/releases/<release-version>/include. The link path for link libraries should be specified as -L$BFDIST/releases/<release-version>/lib/$BFRAC. The libraries needed for linking are listed in Table 7. In addition to these, the zoom libraries -1Exceptions and -12Mutility will be needed; and if you use EVPACK, -1z for zlib. You also need to link against the system’s fortran library. This varies from system to system; here are additional link flags for various systems:

<table>
<thead>
<tr>
<th>System</th>
<th>Flags</th>
</tr>
</thead>
<tbody>
<tr>
<td>Irix</td>
<td>-lftn</td>
</tr>
<tr>
<td>AIX</td>
<td>-lxlf90 -lxlf</td>
</tr>
<tr>
<td>Digital Unix</td>
<td>-tao -Ufor -lf -lFutil -lots -lms -lc_r</td>
</tr>
<tr>
<td>Linux</td>
<td>-lf2c -ldl -lcrpy</td>
</tr>
</tbody>
</table>

(Note that -tao is required for any application which links with DSPACK on Digital Unix.)

If you are using the d0stream interface with DSPACK, you’ll need to be sure that the module d0streamDSPACK.o gets loaded from the library libstream_ds.a. There are two general ways of doing this:
• Extract the module from the library and include it explicitly in your link command.

• Include the header dOStreamDSPACK.hpp explicitly in some other module which you are linking in. Including this header creates a reference to the dOStreamDSPACK module, causing it to be loaded from the library.

Some makefile fragments are now available to try to simplify linking with these libraries.

Including dOom/arch_spec_dOom.mk, for example, will define the make symbol DOOM_LIBES, containing the library specifications which you should add to your link command in order to link with DOOM. If you want to link everything with DOOM, then you could add the value of DOOM_LIBES to LOADLIBES. (This is not done by default, in case you only want to link some programs with the package.)

Here is a list of these scraps:

• DSPACK/arch_spec_dspack.mk: Defines DSPACK_LIBES. (Note: On OSF, this will also add -taso to LDFLAGS, which is required for linking with DSPACK on that platform.)

• dOom/arch_spec_dOom.mk: Defines DOOM_LIBES. This links with only the ‘core’ DOOM library. It does not link with the stream code, or with any of the I/O backends.

• dOostream/arch_spec_dOostream.mk: Defines DO STREAM_LIBES. This links with dOom and the stream code. It does not link with any of the I/O backends.

• dOom_ds/arch_spec_dOom_ds.mk: Defines DOOM_DS_LIBES. This links with DOOM, the stream code, and the DSPACK I/O backend. This scrap also defines DOOM_EV_LIBES, which includes evpack in the link.

If you are using Zoom classes in persistent classes, you should also link with -ldOom_zm.

5.6 Becoming a Developer

It is possible to create a private releases area. When you do this, you must do a full recompilation of any packages that you are interested in, either from the packages area, or of code extracted from cvs. You might do this because you want a more recent version of the code than can be found in the releases area, or because you want to be able to modify the library code. The following is an example session that shows one does this:

setup D0RunII
setup dOcvs
mkdir ~/myrelease
cd ~/myrelease
Table 8: DOOM header files.

<table>
<thead>
<tr>
<th>DOOM class category</th>
<th>Header file</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base class</td>
<td>doom/d0_Object.hpp</td>
</tr>
<tr>
<td>Atomic typedefs</td>
<td>doom/d0_basic_types.hpp</td>
</tr>
<tr>
<td>Strings</td>
<td>do_uti/d0_String.hpp</td>
</tr>
<tr>
<td>Container classes</td>
<td>do_uti/d0_Vector.hpp</td>
</tr>
<tr>
<td></td>
<td>do_uti/d0_List.hpp</td>
</tr>
<tr>
<td></td>
<td>do_uti/d0_PVector.hpp</td>
</tr>
<tr>
<td></td>
<td>doom/d0_RVector.hpp</td>
</tr>
<tr>
<td></td>
<td>do_uti/d0_PList.hpp</td>
</tr>
<tr>
<td></td>
<td>doom/d0_RList.hpp</td>
</tr>
<tr>
<td>Iterators</td>
<td>do_uti/d0_Iterator.hpp</td>
</tr>
<tr>
<td></td>
<td>do_uti/d0_PIterator.hpp</td>
</tr>
<tr>
<td></td>
<td>doom/d0_RIterator.hpp</td>
</tr>
<tr>
<td>References</td>
<td>doom/d0_Ref.hpp</td>
</tr>
<tr>
<td>Stream interface</td>
<td>dostream/d0Stream.hpp</td>
</tr>
<tr>
<td></td>
<td>dostream/d0StreamFactory.hpp</td>
</tr>
<tr>
<td></td>
<td>dostream/d0Key.hpp</td>
</tr>
</tbody>
</table>

newrel -t current test  # Creates directory ~/myrelease/test
cd test
addpkg -h d0om_ds      # Fetch DOOM DSPACK interface code from cvs.
addpkg -h dostream      # Fetch DOOM stream code from cvs.
addpkg -h d0om          # Fetch DOOM code from cvs.
addpkg -h d0_util       # Fetch utility classes from cvs.
addpkg -h CINT          # Fetch CINT code from cvs.
addpkg -h DSPACK        # Fetch DSPACK code from cvs.
gmake installdirs       # Make some directories.
gmake                   # Compile everything

Refer to the code management web page [4] for more information about developer tools.

5.7 DOOM Header Files

Table 8 contains a list of DOOM header files. DOOM header files are included in user programs with the following type of `#include` statement:

```c
#include "doom/d0_Ref.hpp"
```

Note the inclusion of the directory (such as "doom/") in the include statement.
5.8 Generating Linkage Files

Doom supplies a makefile script which can be used to generate the linkage files. To use this, include the line

```
include d0om/d0om_linkage.mk
```

in your GNUmakefile before `standard.mk`. Before including it, you should define the variable `LINKAGE_HPP` to be a list of headers to process through `d0cint` (the file name only, without any leading path component) and `LINKAGE_HPP_DIRS` to be a list of directories in which to search for those headers. The standard include path will be searched, if necessary, to find these directories. If you don’t specify `LINKAGE_HPP_DIRS`, it will default to the name of the current package. If `LINKAGE_REF` is defined, a single object file incorporating all reference headers will be created in `$@`. The object file name is `$(LIB).o`. The object file name is `$(LINKAGE_REF).ref.o`.

By default, both the C++ sources and the reference headers will be generated in `$@`. These defaults can be changed by setting the variables `LINKAGE_CPP_DIR` and `LINKAGE_REF_DIR`. The C++ sources will be added to `LIBCPPFILES`, and (provided `LINKAGE_CPP_DIR` wasn’t overridden) appropriate vpath directives will be issued to allow these sources to be found.

If you wish to prevent `d0cint` from running but want to retain all the dependencies which `d0om_linkage.mk` sets up, define the variable `DONT_RUNCINT`.

By default, when `d0cint` is run from `d0om_linkage.mk`, it will produce no output if it is successful. But if the make variable `VERBOSE` is set, `d0cint` will echo a list of the classes for which it produced linkage information. Further, if you expect `d0cint` to produce warnings for some of your files, define the make variable `DOOM_LINKAGE_ERRORS_EXPECTED`. This will cause `d0om_linkage.mk` to prefix all `d0cint` output with ‘-->', which will prevent the release procedures from claiming that your package is broken.

Example:

```
LIB := libfoo.a

LIBCPPFILES := $(wildcard *.cpp)

# Process the headers foo/class1.hpp
# and foo/class2.hpp.
LINKAGE_HPP_DIRS := foo
LINKAGE_HPP := class1.hpp class2.hpp

include d0om/d0om_linkage.mk
include SoftRelTools/standard.mk
```

5.9 Controlling Generation of Linkage Information

When `d0cint` is run on a header file, it generates dictionary information only for the classes which are defined in that header. In particular, if `A.hpp` defines class `A`,
B.hpp defines class B, and B.hpp includes A.hpp, then running d0cint on B.hpp will
not generate dictionary information for class A — you must run d0cint separately
on A.hpp and B.hpp, even if class B uses class A.

In some cases, however, more control over this process is desirable. This can be
had with the \#pragma linkage and \#pragma nolinkage directives. A directive of the
form

\#pragma linkage class-names

tells d0cint to generate dictionary information for class-names (which should be a
comma-separated list). On the other hand,

\#pragma nolinkage class-names

tells it not to generate dictionary information for classes for which it would ordinarily
do so. Note that these directives take effect only if they are in the outermost header
file (i.e., the one which you named to d0cint).

These directives should usually be used inside an \#ifdef __D0CINT__ construction in order to hide them from translators other than d0cint. (Or use D00M_LINKAGE
and D00M_NOLINKAGE; see section 9.2.)

One use of this facility is to tell d0cint to generate dictionary information for
particular template instantiations (see Section 2.14). It may also be useful for using
classes from external libraries.

One additional mechanism is available. If a class declares a typedef name called
d0om_autolink (it doesn't matter what it is defined as), then that class will always
have linkage information generated, provided that it is used, directly or indirectly, by
another class for which linkage information is being generated. One application of
this is to get linkage information generated for template classes, without requiring the
user to explicitly declare all instantiations of the class. (\#pragma linkage won't work
in this case, because it can only be applied to a specific instantiation, not a template.)
This mechanism is used, for example, to ensure that if user uses a map<K, T> template,
linkage information is generated for the associated pair< const K, T > class.

As an example, here is the definition of std::pair as used by d0cint:

template <class T1, class T2>
struct pair {
    typedef T1 first_type;
    typedef T2 second_type;

    T1 first;
    T2 second;
    pair();
    pair(const T1& x, const T2& y);

    // Flag that this class should have full linkage information
    // generated in each header where it's used.
    typedef int d0om_autolink;
};
Note that this mechanism should not be used for concrete classes deriving from d0_Object; otherwise, you’ll probably end up with multiply defined symbols at link time.

6 Utility Programs

This section lists various utility programs which are available.

6.1 dsdump

The program dsdump can be used to dump out the contents of a DOOM DSPACK (or EVPACK) file. It takes a single argument, the name of the input file, and dumps out all records in the file.

Here is an example of the output from the program. Note that object instances are identified by the class name followed by an integer ID number.

Read record 1 (d0om_ds format version 5)

d0om_DS_Head:1
   d0_Ref<d0_Object> head: T3:2

T3:2
   T3::t3foo bar:
      d0_Int a: 98
      d0_Int b: 99
   d0_Ref<T2<int> > r1: T2<int>:3
   d0_Ref<T2<float> > r2: T2<float>:4

T2<int>:3
   d0om_Unknown_List<T1<int> > b:
      d0_Int a: 4
      d0_Int a: 7
      d0_Int a: 10

T2<float>:4
   d0om_Unknown_List<T1<float> > b:
      d0_Float a: 9.4
      d0_Float a: 6.2
      d0_Float a: 3.4

Note that the data format must be version 5 (written by v00-15-00) or later for this to work.

With the argument --sizes, dsdump will also dump out the sizes of all nonempty DSPACK datasets in the file. The argument --notree will suppress the usual dump of the event contents.
With the option --raw, dsdump will print collections of numeric types as raw hexadecimal dumps. This is useful for looking at raw data. If, in addition, the --byteswap option is given, the values being printed in the hex dump will be byteswapped on little-endian machines.

With the option --examine, dsdump will invoke the DSPACK debugger for each event read. (See Section 6.2.)

The option --precision=prec may also be specified, to set the precision used when writing floating point numbers.

The option --versions will cause dsdump to print the stored version numbers for all classes.

The option --key=key will cause dsdump to seek to the event with event key key before starting to dump. (This works only for EVPACK format files.)

The option --count=N will cause dsdump to exit after printing N events.

The option --only=pattern will cause dsdump to print only objects with names matching the regular expression pattern. Any commas in pattern are replaced with ‘1’, so that a comma-separated list may be used. This option is implemented only on unix platforms.

## 6.2 DSPACK debugger

There is also a DSPACK “debugger,” which can be used to examine the raw DSPACK structures. There are several ways to start the debugger. The first is by running dsdump with the --examine switch (see Section 6.1). In this case, the debugger will be called after each event is read. If you are reading files in EVPACK format (as opposed to plain DSPACK format), this is the only way to use the debugger to look at the data.

The second way to start the debugger is with the standalone dstest program.

The third way is to run DSPACK in client-server mode. The first step is to start the server with ‘dsserver’:

```
$ dsserver
Starting server snyder_d0linux01
```

Next, start the debugger with ‘ds db’:

```
$ ds db
DSPACK 1.520, 10 Mar 1998 (dssd, server: snyder_d0linux01)
dssd>
```

Once the debugger has been started by any of these methods, saying ‘help’ will give you a list of valid commands.

You can open an input file with ‘input’; ‘read’ will then read the next event from the file. (But if you started the debugger through dsdump --examine, an event should already be loaded.)

```
dssd> input tmp/Linux2-KCC_3_3/d0om_ds/ttmp1_ds
```
Read definitions
dsb> read
Read one event

You can see what DSPACK data sets are defined with ‘ls -l’:

dsb> ls -l
Name       Type Id Sect  Size  Items  Nent  Bytes  Free
---        --- --- ---- ---- ---- ---- ----- ----
d0om_DS_Evdat    S  67  1    3    3    1   12    0
Object        S  68  1    1    1    0    0    0
Ref_d0_Object_  S  69  1    1    1    0    0    0
d0om_DS_Head    S  70  1    1    1    1    4    0
T3___t3foo      S  71  1    2    2    0    0    0
T1_int_         S  72  1    1    1    1    3   12    0
_LT1_int_       S  73  1    2    2    0    0    0
T2_int_         S  74  1    2    1    1    8    0
T1_float_       S  75  1    1    1    1    3   12    0
_LT1_float_     S  76  1    2    2    0    0    0
T2_float_       S  77  1    2    1    1    8    0
Ref_T2_int__    S  78  1    1    1    1    0    0    0
Ref_T2_float__  S  79  1    1    1    0    0    0
T3            S  80  1    4    3    1   16    0
Int           S  81  1    1    1    0    0    0
UInt          S  82  1    1    1    0    0    0

The ‘Nent’ column gives the number of entries in that data set in the current record.

To print the definition of a data set, enter its name:

dsb> T3
typedef struct T3___t3foo DS_VARIABLE { /*T3::t3foo;s */
    int_t a;
    /*a */
    int_t b;
    /*b */
} T3___t3foo;

typedef struct Ref_T2_int__ DS_VARIABLE { /*d0_Ref<T2<int> >;r */
    void *ptr;
    /*T2_int__ */
} Ref_T2_int__;

typedef struct Ref_T2_float__ DS_VARIABLE { /*d0_Ref<T2<float> >;r */
    void *ptr;
    /*T2_float__ */
} Ref_T2_float__;

typedef struct T3 DS_VARIABLE { /*T3;o */
    struct T3___t3foo bar;
    /*bar */
    struct Ref_T2_int__ r1;
    /*r1 */
    struct Ref_T2_float__ r2;
    /*r2 */
}
This also prints the definitions of any contained data sets. Note that the names of the
data sets may not match the names of the C++ classes — they are sometimes
"mangled" in order to conform to the restrictions which DSPACK puts on names. You
can see the full name, though, in the comment field on the first line of the definition.

To dump out the data in a data set, enter the data set name preceded by an
asterisk:

dsdump> *T3
Data set: /T3
Type: Structure (at: 0x5000669c)
  1 bar T3_.t3foo
    Type: Structure (at: 0x5000669c)
      1 a Integer : 98
      2 b Integer : 99
  2 r1 Ref_T2_int_
    Type: Structure (at: 0x500066a4)
      1 *ptr Pointer : 0x5000656c T2_int_(1)
  3 r2 Ref_T2_float_
    Type: Structure (at: 0x500066a8)
      1 *ptr Pointer : 0x50006624 T2_float_(1)

This will dump out all entries in the data set. To dump only some of the entries, you
can use a Fortran-like array notation, like ‘T3(3)’ or ‘T3(2:5)’.

To exit from the debugger, use ‘quit’. If you started the debugger through
dsdump --examine the program will read the next event and start the debugger
again. If you were running in client-server mode, the server will remain running, and
you can reconnect to it and resume where you left off by entering ‘ds db’ again. To
kill the server, use the command ‘ds kill’.

A GUI front end to the DSPACK debugger is also available via the command
‘dsmgr’. You must have tcl/tk available for this to work. You should also have a
DSPACK server running before starting dsmgr.

6.3 evdump

The evdump program can be used to dump out the header information in an EVPACK
file. No information about the event contents will be displayed.

Here is an example of the output from the program:

At 0 Type: DSPACK definitions Key: Run number: 1, Event Number: 1
  Reclen: 31395 Comp flag: 5 Uncompr size: 172032 Checksum: 1686699045
  Dictionary offset: 0
At 31395 Type: DSPACK data Key: Run number: 1, Event Number: 1
  Reclen: 2978550 Comp flag: 5 Uncompr size: 8888320 Checksum: 3024682299

56
6.4 evaddindex

The evaddindex program will read through an EVPACK file accumulating event key information. It will then discard any existing index record at the end of the file and write a new one. Any incomplete record at the end of the file will also be discarded. Thus, this program may be used to recover an EVPACK file that was not closed normally.

7 Unknown Objects

An “unknown” object is one for which there is no compiled-in type information; i.e., the linkage file wasn’t linked in. This section describes the behavior of DOOM for such objects.

7.1 Output

Generally, when reference to an unknown object is encountered while writing, the object is ignored and a null reference is written instead. A warning is emitted when this occurs.

However, if the objects being written were read in from another file, special considerations apply. See Section 7.3 below for details.

7.2 Input

When DOOM finds a reference to an unknown object, it can dynamically build dictionary information for that class based on the type information in the data file. (Presently, this works only with the DSPACK back end, and only for data written by at least version v00-15-00 of the library. For other cases, any references to unknown objects on input are simply set to null.) DOOM can then create objects based on this type information. However, any such objects will be instances of the type d0_Unknown_Object, and not instances of the C++ class to which the reference was referring. Therefore, dealing with instantiations of unknown objects requires special care, and this feature is disabled by default.

The behavior of DOOM when a reference to an unknown object is dereferenced is controlled by the Doom_Options::unknown_action(). This option has three possible values:
• RETURN_NULL — Return a null pointer. This is the default. If this happens, a
   warning will be generated by doing a ZMthrow of Exc_Missing_Type.

• THROW_EXCEPTION — Throw an Exc_Missing_Type_Fatal exception.

• MAKE_UNKNOWN — Create an object of type d0_Unknown_Object. This violates
   C++ typing rules, so you should enable this option only if you are prepared to
   deal with that.

   The time at which this option is examined depends on the type of the reference.
   Bare C++ pointers (and auto_ptr’s) must be initialized with a C++ pointer; thus,
   this dereferencing occurs when the pointers are constructed. With the default setting
   of RETURN_NULL, a bare pointer pointing at an unknown object is initialized to null,
   and the unknown object is lost.

   A d0_Ref, however, can be initialized to point at an unknown object. In this case,
   the option is not consulted until the reference is actually dereferenced. A d0_Ref
   pointing at an unknown object will have the following properties:

   • is_null() is false.

   • is_unknown() is true.

   • d0om_type() returns the type of the unknown object.

If an attempt is made to reference the reference with RETURN_NULL in effect, a null
C++ pointer will be returned.

If MAKE_UNKNOWN is enabled, any references which are read may actually be point-
ning at an instance of d0_Unknown_Object. Generally, the only safe way of accessing
information in an object instance will then be through the dictionary information.
Before this can be done, however, the pointer must be converted to a d0_Object
pointer. This cannot be done safely using standard C++ pointer conversions; it
should be done using the conv_to_objptr() method of d0om_Type_Object.

Most analysis code should not set MAKE_UNKNOWN. It is intended to be used by
applications such as data structure browsers.

7.3 Copying

An additional feature is available for the case where a reference to an unknown object
is encountered while writing and the unknown object was read from a file which
contains type information. In that case, the object will automatically be instantiated
for the write. After the write is complete, the object will be automatically deleted
again.

The upshot is that when copying a structure from an input file to an output file,
objects with no compiled-in linkage information can be copied too, provided that they
are reached from known objects by d0_Ref’s and not bare C++ pointers. This option
can be disabled with d0om_Options::make_unknowns_on_write().

Note, however, the following limitation of the current implementation. If you copy
events from several different input files which use different versions of an unknown
type, then the version used for all objects of that type in the output file will be that used in the first input file to use that type.

8 Schema Evolution

This section describes how class definitions may be changed so that old data files are still readable. Note that support for schema evolution depends on the implementation of the I/O backend. This section presently describes the status of the dspack backend, but the others should be similar.

In general, the commonest changes — including adding a new field — are handled automatically. Changing names or types, however, may require special attention.

Note that the schema evolution system described here only deals with changes in the form of the data. Changes in the meaning of the stored data cannot be handled without knowledge of the semantics of the class in question. If you must make such a change, you’ll need to add a version number to your class, and handle the translation yourself.

8.1 Class Names

When reading a data file, DOOM matches classes which were saved to classes in the running program by matching names. This implies that if you change the name of a class, then you will not be able to read instances of that class in old data files. Note that “name” here refers to the fully-qualified class name — moving a class into a different namespace counts as changing its name! Therefore, you should think carefully about the name of a class and its namespace before writing data using it.

If, however, the name of a class must change, there is a feature which can help. In a header file processed through doctest, include a directive like

```
#pragma classalias newclass oldclass;
```

This tells DOOM that the class presently known as newclass was previously known as oldclass. If DOOM encounters the class oldclass while reading a data file, it will map it to newclass. You may provide multiple classalias directives for a given newclass. You should not, however, attempt to create a data file containing both oldclass and newclass. Also, a #pragma classalias directive should probably be put inside a #ifdef _DOCENT_ construction, in order to hide it from other language processors. (Or use DOOM_CLASSALIAS; see section 9.2.) (Note that, at present, only the dspack backend pays attention to this information.)

8.2 Class Members

DOOM translates between saved classes and classes in the program by matching the names of members. Therefore, members may be freely added, deleted, or reordered. Note that, except as described below, renaming a class member is logically the same as deleting a member and then adding a new one.
If a member is deleted, the information contained in the data file for that member is silently ignored. If a member is added, it is initialized to zero when reading a data file which doesn’t contain that member. There is no straightforward way to distinguish between a missing member and a member which just happened to be zero. If such a distinction is important for your class, we suggest that you add a version number member to the class.

Except as noted below, it is not allowed to change the type of a member. If that should happen, an exception will be thrown. This restriction may be relaxed in the future.

A numeric type may be changed into another numeric type. Note that a warning may be generated in cases where this loses precision. This is implemented as a set of predefined conversions (see Section 8.3).

If a member is an array, the size and dimensionality of the array may be changed freely, as long as the base type does not change. A non-array member may also be freely changed to an array, or vice-versa.

In addition, a collection type may be freely changed to any other collection type with the same element type. I.e., you can change list<int> to vector<int>, but not to list<float>.

Note that if a member is deleted from a class, that member name should not be reused in the future. (When reading an old data file, DOOM has no way of knowing that it’s supposed to be a new member.) Therefore, when you delete members from a class, it is a good idea to preserve them in the class documentation. This is also helpful in understanding old data files.

If you must rename a persistent class member but need to be able to continue to read that member in old data files, you can use the memberalias directive, which works in a manner similar to classalias. It has the form:

```
#pragma memberalias newname oldname;
```

Here, newname is looked up in the context in which the directive occurs. If oldname has a class or namespace qualifier, that is ignored. For example,

```
struct A { int a; };
#define __DOCIINT__
#pragma memberalias A:a b;
#undef
```

says that if the member ‘A::a’ isn’t found in the data, DOOM should try looking for ‘A::b’ instead. As for classalias, this directive should probably be placed inside an ifndef __DOCIINT__ construction. (Or use DOOM_MEMBERALIAS; see section 9.2.)

Note that, at present, the memberalias mechanism works only with the DSPSACK backend.

### 8.3 Conversions

The automatic rules DOOM uses for schema evolution suffice for many simple situations. However, some sorts of changes — particularly those that involve changes in
the meaning of the stored data — can never be done completely automatically. To help with such cases, DOOM allows arbitrary converters to be registered to convert between types.

A converter is an instance of an object that derives from `d0om::Converter<To>` (or `d0om::Converter_Base`). It knows how to convert between two types, here called the “source” and “target” types. If DOOM is expecting to see the target type but instead sees the source type, it does not throw an exception (as it would ordinarily do); instead, it runs the converter.

The target type of the conversion must be a type that is known to DOOM. The source type, however, need not be. In such a case, DOOM will automatically define a new type instance to describe the source type that it finds. The converter should then use the DOOM dictionary information to pick fields out of the source instance by name. An example of that will be given below. Due to the feature, the source type is always specified by name only.

Note that this section describes the case where the source and target types have different names. Conversions may also be used to convert between different versions of the same type; see section 8.3.3.

We'll first discuss how converters get registered, then turn to how to write converters themselves.

At this point, only the DSPACK backend handles conversions.

### 8.3.1 Registering Converters

There are two ways in which a converter may be registered: declaratively, by putting a `#pragma convert` directive in a header read by d0cint, or programatically, by calling `d0om::Dictionary::register_converter`.

A converter may be registered by putting a `#pragma convert` directive in a header being read by d0cint. The syntax is:

```plaintext
#pragma convert target-class source-type converter-name
```

Here, `target-class` is the name of the class that is the target of the conversion. This must be a class that is known to d0cint, and it is looked up in the scope that is current where the directive appears.

`source-type` is the name of the source type of the conversion. This name need not be known to d0cint, and it need not be a class type. The name given is simply passed through to the d0cint output, so the name must be complete — including any namespace prefixes — and must not be a typedef name (or use any as template arguments).

`converter-name` is the name of the converter class. This must be a class deriving from `d0om::Converter` (or `d0om::Converter_Base`), and the class must have a default constructor. Again, this name is simply passed through to the d0cint output file, so it should include any namespace prefixes. This class must be defined in the linkage (`_lnk.cpp`) file, but it may be undesirable to include the header defining the converter directly from the header defining the class being converted, as that would mean that all users of that class have a dependency on the converter. This can be
avoided by using the `#pragma linkage include` directive, which emits its argument only in the linkage file. (See Section 9.1.)

Here’s an example:

```cpp
namespace foo {
    struct New_Class {
        int x;
    };

    #ifdef __D0CINT__
    # pragma linkage include "foo/Conv.hpp"
    // New_Class is looked up in the current scope.
    // Old_Class is not looked up here, so it needs
    // to be a complete name.
    # pragma convert New_Class foo::Old_Class Conv;
    #endif
} // namespace foo
```

As mentioned earlier, a converter may also be registered programmatically, by calling `d0om::Dictionary::register_converter`. See the `d0om::Dictionary.hpp` header for details. Here, you must pass it the converter instance. Here’s an example:

```cpp
static Conv conv;
d0om::Dictionary* g = d0om::Dictionary::global ();
g->register_converter ("foo::Old_Class",
    g->get_class_type ("foo::New_Class"),
    conv);
```

The conversion to use should be unambiguous. If you register two conversions with the same source and target types with converters that have different dynamic types, you’ll get a warning (the last one registered takes precedence).

Conversions are also considered when resolving pointers. Consider the following:
you have a pointer declared to point to type A. Type B derives from type A. The pointer actually points to an object of type C, which is not known to DOOM, but there is a conversion from C to B. DOOM will resolve this by looking for any conversions from type C to any types that derive from A. If it finds more than one such candidate, it will issue a warning.

### 8.3.2 Writing Converters

A converter should derive from the class `d0om::Converter`, defined in the header `d0om/d0om_Converter.hpp`. (In some special cases, may be necessary to derive from `d0om::Converter_Base` instead.) Here are the relevant parts of the definition of `d0om::Converter`:
template <class To, class From=char>
class Converter
  : public Converter_Base
{
public:
  // Constructor, destructor.
  Converter () {}
  virtual ~Converter () {}

  // Convert FROM (of type FROM_TYPE) to TO (of type TO_TYPE).
  // The instance at TO will have already been constructed.
  virtual
  void convert (const From* from, const d0om_Type* from_type,
               To* to,   const d0om_Type* to_type) const = 0;
};

The derived class must implement the convert method. When it runs, it should convert the object at from to the object at to, assuming that the instance at to has already been constructed. DOOM passes to the converter the type instances for both the source and target types; this helps in writing generic converters.

Usually, the target type for a converter will be fixed at compile time. In that case, the To template parameter should be set to that type, and the to pointer passed to convert will already be cast to the correct type.

For the source type, though, there are two possibilities. The source type may also be known to DOOM. In that case, the From template argument may be set to the corresponding C++ type and the values manipulated directly. The other possibility is if the source type is not known to DOOM. In this case, the type of the source pointer should be left at its default, and the information from the source instance should be retrieved using the DOOM dictionary information. Examples of these two styles are given below.

First, consider the case where both types are known to DOOM. One might have, for example, these declarations:

struct Old_Class
{
  // Calorimeter cell index, 0-63.
  int iphi;
};

struct New_Class
{
  // Angle of center of calorimeter cell, 0-2pi.
  float phi;
};
#ifndef __DOOM__
#pragma linkage include "foo/Conv.hpp"
#pragma convert New_CLASS Old_CLASS Conv;
#endif

The converter could then be written like this:

#include "d0om/d0om_Converter.hpp"
class Conv
  : public d0om::Converter<New_CLASS, Old_CLASS>
{
  virtual
  void convert (const Old_CLASS* from, const d0om_Type* from_type,
               New_CLASS* to, const d0om_Type* to_type);
};

#include "d0om/d0om_Dictionary.hpp"
#include <cmath>
#include <cassert>

void Conv::convert (const Old_CLASS* from, const d0om_Type* from_type,
                     New_CLASS* to, const d0om_Type* to_type)
{
  // Check that we have the source type we expect.
  static const d0om_Type* expected_from_type = 0;
  if (expected_from_type == 0) {
    d0om_Dictionary* g = d0om_Dictionary::global ()
      ->class_type ("Old_Type");
  }
  assert (from_type == expected_from_type);

  to->phi = from->iphi / 32. * M_PI + (M_PI/64);
}

The second style of converter, which does not assume that the source type is known
to DOOM, is appropriate if you do not want you program to have any dependencies
on the old code. In that case, the declaration of Old_CLASS in the example above
could be dropped, and the converter written like this:

#include "d0om/d0om_Converter.hpp"
class Conv
  : public d0om::Converter<New_CLASS>

64
{ virtual
  void convert (const char* from, const dOom_Type* from_type,
                  New_Class* to, const dOom_Type* to_type);
};

#include "dOom/dOom_Type_Class.hpp"
#include <cassert>

void Conv::convert (const char* from, const dOom_Type* from_type,
                     New_Class* to, const dOom_Type* to_type)
{
  // Get the source type descriptor as a dOom_Type_Class.
  // Check that we have the source type we expect.
  const dOom_Type_Class* fcls =
      dynamic_cast<const dOom_Type_Class*> (from_type);
  assert (fcls != 0);

  // Get the value of member 'iPHi' in the instance
  // of 'fcls' at 'from'.
  int iPHi = fcls->get_int (from, "iPHi");

  // Do the conversion.
  to->PHi = iPHi / 32. * M_PI + (M_PI/64);
}

See the DøOM sources for further information about using the dictionary information.

8.3.3 Version Conversions

Converters can also be used between different versions of the same class. For this to work, you must have declared the version of the class to DOOM with a
#pragma version directive (see section 2.9). You declare a converter from version
n of class C to the current version n the same manner as described above, except
that for the source name you use the special form “C-vn”. This converter is used
when reading any instances of version n and earlier, unless there is another converter
registered with a smaller version.

For example, suppose we have the declarations

struct A {};
#pragma version A 6;
#pragma convert A A-v2 Conv1;
#pragma convert A A-v4 Conv2;
In this case, the converter Conv1 will be used for versions 1 and 2, Conv2 will be used for versions 3 and 4, and the default conversion rules will be used for any later versions. (Note that if the version read is larger than the current version, the default conversion rules are always used.)

8.3.4 Implicit Conversions

DOOM provides some implicit conversions, in addition to those that have been explicitly registered.

If there is a conversion from type A to type B, then there is an implicit conversion from any collection of A to any collection of B.

8.3.5 Predefined Conversions

DOOM registers some conversions by default.

There are six predefined conversions, between all of int, float, and double. However, the three of these that narrow the type give a warning when they run.

8.4 nowrite

There is an additional mechanism available that may be helpful when changing class members. A member may be tagged as “no-write,” using #pragma nowrite, which works in a manner similar to #pragma transient. For example:

```c
struct foo
{
    int a;
};

#ifdef __D0CINT__
#pragma nowrite foo::a; // foo::a should not be written.
#endif
```

Class members that are tagged as nowrite will be read in from input files, if they exist, but will not be written to output files. This can be used to assist in schema evolution, as sketched in the following example.

Suppose you have a class foo:

```c
struct foo
: public d0_Object
{
    A a;
    D0_OBJECT_SETUP (foo);
};
```
You want to change ‘A a’ to ‘B b’, while retaining the ability to read old data files. One solution would be to maintain both members and add a conversion, as outlined here:

```cpp
struct foo
  : public d0_Object
{
  A a;
  B b;

  void activate ();
  D0_OBJECT_SETUP (foo);
};

void foo::activate ()
{
  if (a.has_info() && !b.has_info()) {
    convert_a_to_b (a, b);
    a.clear();
  }
}
```

This will work, but it has the disadvantage that the declaration “A a” will take up some space in the output file. This overhead may be avoided by declaring the member a as `nowrite`:

```
#pragma nowrite foo::a;
```

### 8.5 Other Points

DOOM pays no attention to methods. Therefore, they may be freely changed, without affecting the ability to access stored data. The same applies to static data members and data members declared as transient.

DOOM expands all `typedef` names before writing to a data file. Therefore, typedef aliases for types may be freely changed.

### 9 d0cintPragma Reference

#### 9.1 Pragma Listing

The section lists some of the pragma directives accepted by d0cint. (cint proper recognizes some additional directives, which are probably not generally useful and are thus not documented here.)

These directives should all be on a single source line. They may optionally be ended with a semicolon, but that is not required. If they are used in source files
which are to be read by a C++ compiler, they should probably be put inside an
ifdef __DOCINT__ construction, in order to hide them from the compiler. (Or use
the macro variants listed in section 9.2.)

- #pragma classalias newclass oldclass
  Declare that newclass was previously known as oldclass. See Section 8.
  Example:

  #ifdef __DOCINT__
  # pragma classalias ns::foo foo;
  // Class ‘ns::foo’ used to be known as just ‘foo’.
  #endif

- #pragma extendclass class
  This pragma allows one to add to the definition of an already existing class.
  It should be followed on the next line by an open brace, then the body of the
  material to be added, then a closing brace. Note that the member protection
  is reset to the default; thus, when extending a class, all members will be
  considered private unless you include a public: keyword.
  This construction can be useful for injecting typedefs required by DOOM into
classes defined in existing header files.
  Example:

  class foo {
  
  #ifdef __DOCINT__
  # pragma extendclass foo
  {
  public:
    // Inject this d0om typedef into class foo.
    typedef foo_adapter d0om_collection_adapter;
  }
  #endif

- #pragma include_next "header"
  This pragma searches the include path supplied to d0cint for header. Unlike
  include, however, it does not stop at the first match it finds, but continues
  searching until it finds a second match. (Any paths containing ‘/d0cintinc/’
  are also skipped.) That header is then included. This is useful for writing cint
  wrapper headers around existing headers.
  Note also that this directive accepts only the "" form of inclusion, not <>, and
  that it searches only the directories explicitly specified from the command line
  with -I switches.
  Example:
#pragma include_next "Package/foo.hpp"

- **#pragma linkage** classes
  Tell d0cint to generate linkage information for classes. This only has an effect if it is in the outermost header file. See Section 5.9.

  Example:

  ```
  #ifdef __DOCINT__
  # pragma linkage foo;  // Generate linkage info
                      // for class foo.
  #endif
  ```

- **#pragma linkage**include text
  Have d0cint emit #include text in the linkage file. See Sections 2.2.5 and 2.15 for usage examples.

  Example:

  ```
  #ifdef __DOCINT__
  # pragma linkageinclude "foo.hpp"
                     // Include foo.hpp from the linkage source.
  #endif
  ```

- **#pragma memberalias** newname oldname
  Declare that the class member newname was previously known as oldname. See Section 8.2.

  In this construction, newname is looked up in the context in which the directive appears. Any class or namespace qualifiers present in oldname are ignored. The class must have a persistent member named newname, and must not have one named oldname.

  Example:

  ```
  struct A { int a; };

  #ifdef __DOCINT__
  # pragma memberalias A::a b;
                     // Member ‘A::a’ used to be known as ‘A::b’.
  #endif
  ```

  This tells DOOM that if it can’t find the member A::a in the data, it should also try looking for A::b.
• **#pragma no linkage** classes
  Tell doocint to not generate linkage information for classes. This only has an effect if it is in the outermost header file. See Section 5.9.

  Example:

  ```
  #ifdef __DOCINT__
  # pragma no linkage foo; // Don’t generate linkage info
                  // for class foo.
  #endif
  ```

• **#pragma nowrite** members
  Tell doocint that members are should be read but not written. See Section 8.4.

  Example:

  ```
  struct foo
  {
    int a;
  };

  #ifdef __DOCINT__
  # pragma nowrite foo::a; // foo::a should not be written.
  #endif
  ```

• **#pragma pack** (packspec) members
  Tell DOOM to attempt to pack members as described by packspec. See Section 2.18.

  Example:

  ```
  struct foo
  {
    int a;
    int b;
  };

  #ifdef __DOCINT__
  // Pack a,b into a single int.
  # pragma pack (nbits=16) foo::a, foo::b;
  #endif
  ```

• **#pragma transient** members
  Tell doocint that members are transient. See Section 2.7.

  Example:
struct foo
{
    int a;
};

#ifndef __DOCINT__
    #pragma transient foo::a; // foo::a is transient
#endif

• #pragma version class version
Tell doCint that class class has version version. The name class is looked up in
the context in which the directive appears. The version number version is an
expression that evaluates to a constant integer. It is an error to attempt to alter
the version number of a class. (Multiple #pragma version directives for a class
are permitted as long as the version numbers are the same.) See Section 2.9.
Example:

struct foo
{
    int a;
};

#ifndef __DOCINT__
    #pragma version foo 5;
    #pragma version foo 3+2; // Ok -- same version number.
#endif

9.2 Pragma Macros
The header doom/doomPragma_macros.hpp contains alternate, macro versions of
most of the doCint pragma directives. The advantage is that the macros can be
defined to expand to something harmless if doCint is not running; thus, you can avoid
cluttering your source with #ifdef __DOCINT__ directives. For example, instead of
writing

... #ifdef __DOCINT__
    #pragma transient A::b;
#endif

you can write

#include "doom/doomPragma_macros.hpp"

... DOOM_TRANSIENT (A::b);
Here is the list of defined macros:

- DOOM_CLASSALIAS(newcls, oldcls)
- DOOM_CONVERT(to, from, conv)
- DOOM_LINKAGE(name)
- DOOM_LINKAGEINCLUDE(path)
- DOOM_MEMBERALIAS(newmem, oldmem)
- DOOM_NOLINKAGE(name)
- DOOM_NOWRITE(name)
- DOOM_PACK(packspec, field)
- DOOM_TRANSIENT(name)
- DOOM_VERSION(cls, vers)

A Some d0_Ref<T> Details

This section contains some of the details of how class d0_Ref<T> is implemented and how it interacts with the class d0_Object. The class diagram for d0_Ref<T> is shown in Fig. 8. Observe that, in addition to being associated with the class d0_Object, d0_Ref<T>`s are associated with another class d0om_Indptr, or “indirect pointers.” There can be at most one d0om_Indptr associated with any instance of d0_Object. An object’s reference count, if any, is part of its associated d0om_Indptr. There are several way in which the classes shown in Fig. 8 can be instantiated.

1. Null references are not associated with any instance of d0_Object or any indirect pointer.

2. Static and automatic d0_Object’s have no associated indirect pointer or reference count. Such non-reference-counted objects may still be pointed to by a d0_Ref<T>.

3. Instances of d0_Object that are created on the heap using the new operator are associated with one indirect pointer of type d0om_Transient_Indptr and one or more d0_Ref<T>`s.

4. Except as provided for in the following case, objects read from dSPACK are associated with one indirect pointer of type d0om_DS::Indptr and one or more d0_Ref<T>`s. Instantiation of the corresponding d0_Object is deferred until one of the associated d0_Ref<T>`s is dereferenced.
5. Objects that have been read from DSPACK using bare C++ pointers have an associated indirect pointer of type d0om_DS::Indptr, but are never allowed to be pointed to by a d0_Ref<T>. DOOM enforces this by setting the flag _noref in d0om_Indptr to be true. In this case, the instantiation of the corresponding d0_Object can not be deferred, as it would be for d0_Ref<T>.

Cases three and four represent the typical non-trivial uses of d0_Ref<T>. In either case, the number of d0_Ref<T>’s that are pointing to an indirect pointer is maintained in the reference count that is part of the indirect pointer. Should the reference count ever reach zero, the indirect pointer and its associated d0_Object are deleted.

If I/O methods other than DSPACK are added to DOOM, it will be necessary to create additional subclasses of d0om_Indptr, as well as of d0Stream.

B DOOM Dictionary Classes

This section summarizes DOOM’s dictionary classes. A diagram of the dictionary classes is shown in Fig. 9. Each C++ data type or subtype is described by a class
derived from abstract class `d0om_Type`. Each DOOM type is identified by a character string name and by subtype. Each DOOM subtype falls into one of the following four categories, each of which corresponds to one of the subclasses of `d0om_Type`.

1. Atomic types.
2. Collections.
3. References.
4. Classes.

In addition to these classes which describe types, there is an additional class `d0om_Dictionary` which manages the type instances. A `d0om_Dictionary` instance owns a collection of type instances, and has methods for creating them and looking them up.

There is one distinguished `d0om_Dictionary` instance, called the “global” dictionary. It can be found using the static method `d0om_Dictionary::global()`. Other dictionaries are “local.” When a local dictionary is searched for a type, if the type isn’t found, the global dictionary is automatically searched as well.

The type objects for classes and objects are created in the (static) routine `d0om_type_setup()` in each linkage source file. This gets called during initialization (from `d0om_init`).

### B.1 Atomic Types

Atomic types are one of the types listed in Section 2.1, and are described by class `d0om_Type_Atomic`. Class `d0om_Type_Atomic` adds a single enumerated datum to `d0om_Type` which identifies the atomic type.

### B.2 Collections

Collection types are one of the containers listed in Section 2.2, and are described by class `d0om_Type_Collection`. Class `d0om_Type_Collection` has as its data an enumerated collection type, and a link to the contained type, which can be any DOOM type.

### B.3 References

Class `d0om_Type_Reference` is used to describe bare C++ pointers, bare C++ references, and `d0_Refer<T>`'s. Class `d0om_Type_Reference` contains an enumerated reference type and a link to the pointed to type, which must derive from `d0_Object`, and which is described by class `d0om_Type_Object`. 

74
Figure 9: Class diagram for dictionary classes.
B.4 Classes

DOOM classes are described by class d0om_Type_Class, whether or not they are derived from d0_Object. Information about the base classes and data fields that make up the class are stored in class d0om_Type_Class itself (details not shown). Classes that don’t derive from d0_Object are instantiated as a concrete instances of class d0om_Type_Class. Classes that derive from d0_Object are instantiated as subclasses of class d0om_Type_Object. Concrete and abstract classes are described respectively by instances of the template classes d0om_Type_Objclass<T> and d0om_Type_Abstract_Objclass<T>, where the template argument T is the type of the class being described.

B.5 Accessing the Dictionary classes

The complete dictionary interface is too complicated to completely document here. And end users should not normally need to access the dictionary. However, this section contains some hints about how to gain access to dictionary information.

The following methods of d0_Object allow the programmer to determine the type of any instance of a class that is derived from d0_Object.

virtual const d0om_Type_Object* d0om_type() const; // Dynamic type
static d0om_Type_Object* d0om_type_static(); // Static type

The class d0om_Object_Walker uses the dictionary information to visit each data member of a class instance and perform user-specified processing on them. See d0om_ds/src/utils/dsdump.cpp for an example of its use.

C  DSPACK Specific I/O Interface

This section documents the I/O interface presented by the DSPACK interface classes. This interface is not intended to be used by ordinary users. It is included here for completeness.

Writing is handled by class d0om_DS::Outunit (which is defined by the header file d0om_ds/Outunit.hpp). Reading is handled by class d0om_DS::Inunit (header file d0om_ds/Inunit.hpp)  The following program fragment shows the steps involved in writing an event.

```
#include "d0_util/d0_String.hpp"
#include "d0om/d0_Object.hpp"
#include "d0om/d0_Ref.hpp"
#include "d0om_ds/Outunit.hpp"
#include "Event.hpp"

int main()
{

```
d0_Ref<Event> rEvent;

// System initialization. The argument name is passed to DSPACK's
// initialization routine, dsinit.

d0om_init("test");

// Open output file

d0om_DS::Outunit*  own = d0om_DS::Outunit::open("test.ds");

// Write event. Every class referenced in Event is also written out.

own->write_obj (rEvent);

// Close output file.

own->close(); // Close output file

The following is an example of a reading program.

#include "d0_util/d0_String.hpp"
#include "d0om/d0_Object.hpp"
#include "d0om/d0_Ref.hpp"
#include "d0om_ds/Inunit.hpp"
#include "Event.hpp"

int main()
{
    d0_Ref<Event> rEvent;

    // System initialization.

    d0om_init("test");

    // Open input file.

    d0om_DS::Inunit* iun = d0om_DS::Inunit::open("test.ds");

    // Event reading loop. Read a new DSPACK record.

    while(iun->read_dsrec()) {


// Return the first object of class Event in the current record.

rEvent = D0_HCAST((Event)) (iun->getref(1, Event::d0om_type_static()));
}

// Close input file.

iun->close();

C.1 DØOM to DSPACK Interface Classes

This section contains a more detailed description of the classes which provide the mapping between the DØOM data model and its I/O interface; and the data structures, files and I/O mechanisms of the DSPACK package. The DØOM stream I/O interface is abstract and therefore independent of any particular I/O mechanism. However, each specific stream implementation requires a set of interface classes through which the actual translation of data between C++ objects and the data structures of the I/O mechanism occur and through which the mapping between an I/O stream and the physical file I/O mechanisms is accomplished.

The interface between DØOM and DSPACK consists of the following elements

1. Specific sub-class of d0Stream for DSPACK I/O
2. Mapping classes between DØOM Persistent classes and DSPACK datasets, including a class which represents a DSPACK directory
3. Pointer mapping classes
4. DSPACK File Identifier representation classes
5. DSPACK class through which all calls to DSPACK are made
6. Exception handling

C.2 d0StreamDSPACK

This sub-class of d0Stream currently reads and writes events from a d0Stream which has been mapped to a DSPACK data file. An event in a DSPACK data file consists of a number of interdependent DSPACK datasets, treated as a single logical record.

However, in addition to this basic read/write file stream I/O, an additional stream read/extract capability is provided - to return a pointer to a named class based on a key (which maps one-to-one onto a DØOM class name). This type of read/extract is only performed when the key, a character string, consists of a minus sign (-) followed by the name of a class.
The implementation also allows for an “event” to be written out consisting of
any tree of DOOM persistent objects starting from a specific d0_object. Checks for
circular pointer references are implemented.

Creation of a d0StreamDSPACK instance returns an open stream behind which all
of the needed objects for mapping between stream I/O and DSPACK I/O and between
C++ classes and DSPACK datasets have been created and populated. This involves
creation of an appropriate d0om_DS::Unit instance (either for input or output) and
creation of a matching “Directory” object for the stream. The “Directory” object
holds various DSPACK indices and also manages the collection of objects which serve
to provide data mapping functions - see Saveable classes described below.

A d0StreamDSPACK object when instantiated:

1. opens a DSPACK data file, for either read or write, using a d0om_DS::Unit class
   object as the representation of the DSPACK input or output file and its file
   identifier.

2. creates a directory object to store and manage the map between DSPACK dataset
   objects and C++ classes. If data is being read then the DSPACK header file,
   which contains 'self-defining' complete definitions of all objects that may be
   found in the file, is first read and used to construct the directory.

3. creates instances of Saveable classes - one for each type of persistent object to
   be mapped between DSPACK and DOOM

C.3 I/O stream to file ID mapping classes

The class d0om_DS::Unit allocates and manages DSPACK file IDs (or unit numbers
as they are sometimes called). There are specialized sub-classes for input units and
output units.

d0om_DS::Inunit (subclass of d0om_DS::Unit)
d0om_DS::Outunit (subclass of d0om_DS::Unit)

C.4 Mapping classes between DOOM persistent classes and
DSPACK datasets

C.4.1 d0om_DS::Dir

This class, together with its partner class d0om_DS::Dirrep, forms an object registry
for DSPACK datasets. It tracks the object index, DSPACK handle, section location in
DSPACK for each object. It creates Saveable objects for each type of object being
managed. It keeps a map of complete descriptive information for each field of each
object.

A class d0om_DS::Dirchange provides a mechanism for changing the directory for
a d0StreamDSPACK stream.

A class d0om_DS::Rawdir is used to manage the creation and allocation of DSPACK
directories.
C.4.2 Saveable Base Class

doom_DS::Saveable is the base class for classes which play the role of ‘Agents’ in the conversion of data between DOOM C++ class instances and elements in DSPACK datasets. A doom_DS::Saveable instance is associated with a particular DSPACK directory. For each directory and for each type of DOOM persistent class present a doom_DS::Saveable sub-class of matching type is instantiated and used to carry out the mapping and data conversion operations.

The base class handles the common functions needed for all DOOM persistent classes, namely:

- the generic mapping from the C++ class name to a valid DSPACK dataset name. This may involve mangling the class name to conform to DSPACK names.

- access to DSPACK dataset handles

- the generic movement of N data items between the C++ memory location and the corresponding DSPACK memory buffer, including reservation of space in the DSPACK memory buffer. These methods, which save and restore data, are normally overridden by subclass methods.

Subclasses of doom_DS::Saveable handle the specific data translation functions involved in mapping each type of DOOM persistent class to the elements of its DSPACK dataset representation.

C.4.3 doom_DS::Class and doom_DS::Classrep

Saveable subclasses for different types of DOOM persistent classes.

These two classes together hold the mapping between C++ class member fields and DSPACK fields for a particular class. They are logically one mapping class, but are sub-divided into two classes because of compiler/template limitations. Each C++ class member field is represented in a map table by

- field name.

- offset in the C++ structure.

- number of adjacent identical elements in the C++ structure.

- offset in the DSPACK structure (or -1 if doesn’t exist in DSPACK).

- number of adjacent identical elements in the DSPACK structure.

- the type of Saveable for this member field.

- flag for if the field represents a base subobject.
d0om_DS::Class methods which save and restore data use the mapping table to
determine how to allocate space and initialize memory. They then perform the actual
translation and copy of the fields.

d0om_DS::Object is a subclass of d0om_DS::Class. All C++ classes which inherit
from d0_Object are mapped and translated by the subclass d0om_DS::Object of
d0om_DS::Class which, in addition to calling the base class methods to save and
restore, also performs the activation and deactivation of an object instance as it is
read in (restored) or written out (saved).

C.4.4 d0om_DS::Collection

This subclass handles the save and restore of the data structures representing a
Doom Container (aka Collection) class and also iterates over the elements of the
Container, invoking the save and restore methods of the appropriate Saveable type
for each of the contained instances. All Container collections are represented by two
separate DSPACK datasets. One dataset contains a two element structure denoting
the number of items in the collection and a pointer to the first collection element.
The other dataset stores the actual collection elements contiguously. All Doom Con-
tainer types are handled in the same way. For ordered collections the order of the
elements is significant.

C.4.5 d0om_DS::Atomic

This subclass, and its more specific derived classes, handle the mapping of Doom
atomic data types. The fixed length fundamental atomic data types - Integer, Short,
Character, Boolean, Float and Double are all handled in a similar way by the
d0om_DS::Fundamental classes. These handle the translation of the fundamental
atomic types between a C++ field and the DSPACK dataset named for the specific
data type - e.g. "INT4" for Integers.

All supported fundamental atomic types except for Double require no fur-
ther code to perform the mapping beyond that provided through the C++ lan-
guage support. The one exception to this is Double, for which a supporting class
d0om_DS_double_hack is needed.

C.4.6 d0om_DS::String and d0om_DS::Stringrep

The mapping between a C++ atomic field and a DSPACK dataset element is handled
slightly differently for string atomic types. A string is represented in two separate
datasets; one storing a two-element structure containing a pointer to the start of
the string and its length, and the other storing the actual body of the string. The
d0om_DS::Stringrep class merely provides the mapping to named DSPACK dataset
"x.CHAR4" which is used for storage of the body of strings - packed into an integral
number of 4 byte character string elements.
The mapping between a C++ member field which stores either a C++ bare pointer or a d0Ref pointer is handled by this class or one of its derived classes

- `d0om_DS::Reference_Pointer`: for handling C++ pointers or references.
- `d0om_DS::Reference_D0Ref`: for handling d0_Ref objects.
- `d0om_DS::Reference_DynRef`: for handling DynRef objects.
- `d0om_DS::Reference_Auto_Ptr`: for handling auto_ptr objects.

All types of references contained in C++ classes are implemented in their DSpaceK representation as DSpaceK pointers. The mapping between references and DSpaceK pointers is quite tricky and has many checks to

- ensure that there are no circular pointer references
- handle polymorphism
- check for potential conflicts between C++ bare pointers and DOOM smart pointers

C.4.8  `d0om_DS::Dummy`

Although this class is derived from `d0om_DS::Saveable` it does not carry out mapping functions in the same way as the other sub-classes. Rather, it is used by those other classes when, in the course of mapping between a DSpaceK dataset and C++ classes, it is discovered that a particular dataset contains a field which has no corresponding field in its C++ class. An instance of a `d0om_DS::Dummy` class is then created by the Saveable class handling the mapping. This instance is used merely as a temporary memory storage location so that the normal mapping operations of locating space, clearing/zeroing space, and performing a copy can proceed into a "dummy" data area. An instance of `d0om_DS::Dummy` is not associated with a particular DSpaceK directory; it is created and destroyed as needed by the `d0om_DS::Saveable` instance.

C.5  Location mapping classes

C.5.1  `d0om_DS::Loc`

Objects are located in DSpaceK using a triple

(file_offset,Saveable,index)

This triple is represented by the class `d0om_DS::Loc`.  

82
C.5.2  d0om_DS::Indptr

This class is a DSPACK specific subclass of d0om_Indptr which provides the methods to locate an object in memory using d0om_DS::Loc objects.

C.5.3  d0om_DS::Bound_Pointer

???

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References


