Embedded C++/Hybrid Mapping

Getting Started Guide

This document is available in the following formats: XHTML, PDF, and PostScript.

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Preface

About This Document

The goal of this document is to provide you with an understanding of the C++/Hybrid programming model and allow you to efficiently evaluate XSD/e against your project's technical requirements. As such, this document is intended for embedded C++ developers and software architects who are looking for an embedded XML processing solution. Prior experience with XML and C++ is required to understand this document. Basic understanding of XML Schema is advantageous but not expected or required.

More Information

Beyond this guide, you may also find the following sources of information useful:

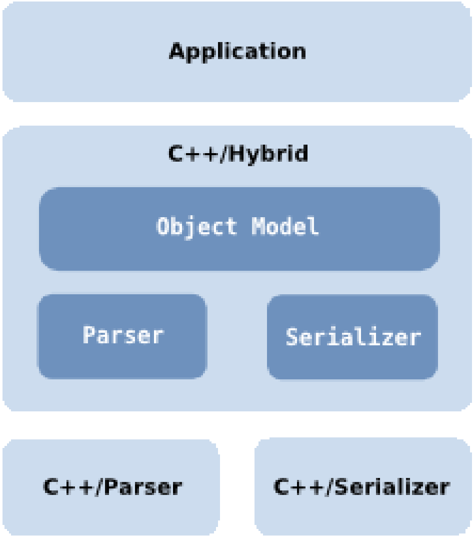
- XSD/e Compiler Command Line Manual
- Embedded C++/Parser Mapping Getting Started Guide. The C++/Hybrid mapping uses C++/Parser for XML parsing.
- Embedded C++/Serializer Mapping Getting Started Guide. The C++/Hybrid mapping uses C++/Serializer for XML serialization.
- The `INSTALL` file in the XSD/e distribution provides build instructions for various platforms.
- The `examples/cxx/hybrid/` directory in the XSD/e distribution contains a collection of examples and a README file with an overview of each example.
- The xsde-users mailing list is the place to ask technical questions about XSD/e and the Embedded C++/Hybrid mapping. Furthermore, the archives may already have answers to some of your questions.

1 Introduction

Welcome to CodeSynthesis XSD/e and the Embedded C++/Hybrid mapping. XSD/e is a validating XML parser/serializer and data binding generator for mobile and embedded systems. Embedded C++/Hybrid is a W3C XML Schema to C++ mapping that represents the data stored in XML as a light-weight, statically-typed, in-memory object model.

1.1 Mapping Overview

Based on a formal description of an XML vocabulary (schema), the C++/Hybrid mapping produces a tree-like data structure suitable for in-memory processing. The core of the mapping consists of C++ classes that constitute the object model and are derived from types defined in XML Schema. The C++/Hybrid mapping uses the APIs provided by the Embedded C++/Parser and Embedded C++/Serializer mappings to perform validation and parsing of XML to the object model and validation and serialization of the object model to XML. The following diagram illustrates the high-level architecture of the C++/Hybrid mapping:



The use of well-defined APIs presented by the C++/Parser and C++/Serializer mappings for XML parsing and serialization allows a number of advanced techniques, for example, customization of parsing and serialization code, filtering of XML during parsing or object model during serialization, as well as the hybrid, partially even-driven, partially in-memory processing where the XML document is delivered to the application as parts of the object model. The last feature combines the ease and convenience of the in-memory processing model with the ability to minimize the use of RAM and process documents that would otherwise not fit into memory.

The Embedded C++/Hybrid mapping was specifically designed and optimized for mobile and embedded systems where hardware constraints require high efficiency and economical use of resources. As a result, the generated parsing and serialization code is 2-10 times faster than general-purpose XML processors while at the same time maintaining extremely low static and dynamic memory footprints. For example, an executable that performs validating XML parsing and serialization can be as small as 150KB in size. The size can be further reduced by disabling support for parsing or serialization as well as XML Schema validation.

The generated code and the runtime library are also highly-portable and, in their minimal configuration, can be used without STL, RTTI, iostream, C++ exceptions, and with the minimal use of C++ templates.

A typical application that uses the C++/Hybrid mapping for XML processing performs the following three steps: it first reads (parses) an XML document to an in-memory object model, it then performs some useful computations on that object model which may involve modification of the model, and finally it may write (serialize) the modified object model back to XML. The next chapter presents a simple application that performs these three steps. The following chapters describe the Embedded C++/Hybrid mapping in more detail.

1.2 Benefits

Traditional XML access APIs such as Document Object Model (DOM) or Simple API for XML (SAX) as well as general-purpose XML Schema validators have a number of drawbacks that make them less suitable for creating mobile and embedded XML processing applications. These drawbacks include:

- Generic representation of XML in terms of elements, attributes, and text forces an application developer to write a substantial amount of bridging code that identifies and transforms pieces of information encoded in XML to a representation more suitable for consumption by the application logic.
- String-based flow control defers error detection to runtime. It also reduces code readability and maintainability.
- Lack of type safety and inefficient use of resources due to the data being represented as text.
- Extra validation code that is not used by the application.
- Resulting applications are hard to debug, change, and maintain.

In contrast, a light-weight, statically-typed, vocabulary-specific object model produced by the Embedded C++/Hybrid mapping allows you to operate in your domain terms instead of the generic elements, attributes, and text. Native data types are used to store the XML data (for example, integers are stored as integers, not as text). Validation code is included only for XML Schema constructs that are used in the application. This results in efficient use of resources and compact object code.

Furthermore, static typing helps catch errors at compile-time rather than at run-time. Automatic code generation frees you for more interesting tasks (such as doing something useful with the information stored in the XML documents) and minimizes the effort needed to adapt your applications to changes in the document structure. To summarize, the C++/Hybrid object model has the following key advantages over generic XML access APIs:

- **Ease of use.** The generated code hides all the complexity associated with parsing and serializing XML. This includes navigating the structure and converting between the text representation and data types suitable for manipulation by the application logic.
- **Natural representation.** The object representation allows you to access the XML data using your domain vocabulary instead of generic elements, attributes, and text.
- **Concise code.** With the object representation the application implementation is simpler and thus easier to read and understand.
- **Safety.** The generated object model is statically typed and uses functions instead of strings to access the information. This helps catch programming errors at compile-time rather than at runtime.

- **Maintainability.** Automatic code generation minimizes the effort needed to adapt the application to changes in the document structure. With static typing, the C++ compiler can pin-point the places in the client code that need to be changed.
- **Efficiency.** If the application makes repetitive use of the data extracted from XML, then the C++/Hybrid object model is more efficient because the navigation is performed using function calls rather than string comparisons and the XML data is extracted only once. The runtime memory usage is also reduced due to more efficient data storage (for instance, storing numeric data as integers instead of strings) as well as the static knowledge of cardinality constraints.

  Furthermore, the generated XML parsing and serialization code combines validation and data-to-text conversion in a single step. This makes the generated code much more efficient than traditional architectures with separate stages for validation and data conversion.

2 Hello World Example

In this chapter we will examine how to parse, access, modify, and serialize a very simple XML document using the generated C++/Hybrid object model as well as the XML parser and serializer. The code presented in this chapter is based on the `hello` example which can be found in the `examples/cxx/hybrid/` directory of the XSD/e distribution.

2.1 Writing XML Document and Schema

First, we need to get an idea about the structure of the XML documents we are going to process. Our `hello.xml`, for example, could look like this:

```
<?xml version="1.0"?>
<hello>

  <greeting>Hello</greeting>

  <name>sun</name>
  <name>earth</name>
  <name>world</name>

</hello>
```

Then we can write a description of the above XML in the XML Schema language and save it into `hello.xsd`:

```
<?xml version="1.0"?>
<xs:schema xmlns:xs="http://www.w3.org/2001/XMLSchema">

  <xs:complexType name="hello">
    <xs:sequence>
```

```
      <xs:element name="greeting" type="xs:string"/>
      <xs:element name="name" type="xs:string" maxOccurs="unbounded"/>
    </xs:sequence>
  </xs:complexType>

  <xs:element name="hello" type="hello"/>

</xs:schema>
```

Even if you are not familiar with XML Schema, it should be easy to connect declarations in `hello.xsd` to elements in `hello.xml`. The `hello` type is defined as a sequence of the nested `greeting` and `name` elements. Note that the term sequence in XML Schema means that elements should appear in a particular order as opposed to appearing multiple times. The `name` element has its `maxOccurs` property set to `unbounded` which means it can appear multiple times in an XML document. Finally, the globally-defined `hello` element prescribes the root element for our vocabulary. For an easily-approachable introduction to XML Schema refer to XML Schema Part 0: Primer.

The above schema is a specification of our XML vocabulary; it tells everybody what valid documents of our XML-based language should look like. The next step is to compile the schema to generate the object model and the parser.

2.2 Translating Schema to C++

Now we are ready to translate our `hello.xsd` to C++. To do this we invoke the XSD/e compiler from a terminal (UNIX) or a command prompt (Windows):

```
$ xsde cxx-hybrid --generate-parser --generate-aggregate hello.xsd
```

This invocation of the XSD/e compiler produces three pairs of C++ files: `hello.hxx` and `hello.cxx`, `hello-pskel.hxx` and `hello-pskel.cxx`, as well as `hello-pimpl.hxx` and `hello-pimpl.cxx`. The first pair contains the object model classes. The second pair contains parser skeletons. Parser skeletons are generated by the C++/Parser mapping which is automatically invoked by C++/Hybrid. For now we can ignore parser skeletons except that we need to compile them and link the result to our application. The last pair of files contains parser implementations. They implement the parser skeletons to create and populate the object model types from XML data. The generation of parser skeletons and parser implementations is requested with the `--generate-parser` XSD/e compiler option.

You may be wondering what is the `--generate-aggregate` option for. This option instructs the XSD/e compiler to generate parser and, as we will see later, serializer aggregates. The generated parser implementation files mentioned above contain a separate parser implementation class for each type defined in XML Schema. These parser implementations need to be instantiated and connected before we can use them to parse an XML document. When you specify the `--generate-aggregate` option, the XSD/e compiler generates a class (in the parser implementation files), called parser aggregate, for each global element defined in the schema (you can also generate a parser aggregate for a type as well as control for which global elements parser aggregates are generated, see the XSD/e Compiler Command Line Manual for more information). A parser aggregate instantiates and connects all the necessary parser implementations needed to parse an XML document with a given root element. We will see how to use the parser aggregate for the `hello` root element in the next section.

The following code fragment is taken from `hello.hxx`; it shows what the C++ object model for our "Hello World" XML vocabulary looks like:

```
class hello
{
public:
  hello ();

  // greeting
  //
  const std::string&
  greeting () const;

  std::string&
  greeting ();

  void
  greeting (const std::string&);

  // name
  //
  typedef xsde::string_sequence name_sequence;
  typedef name_sequence::iterator name_iterator;
  typedef name_sequence::const_iterator name_const_iterator;

  const name_sequence&
  name () const;

  name_sequence&
  name ();

private:
  ...
};
```

The `hello` C++ class corresponds to the `hello` XML Schema type. For each element in this type a set of accessor and modifier functions are generated inside the `hello` class. Note that the member functions for the `greeting` and `name` elements are different because of the different cardinalities these two elements have (`greeting` is a required single element and `name` is a sequence of elements).

It is also evident that the built-in XML Schema type `string` is mapped to `std::string`. The internal `string_sequence` class that is used in the `name_sequence` type definition has an interface similar to `std::vector`. The mapping between the built-in XML Schema types and C++ types is described in more detail in Chapter 5, "Mapping for Built-in XML Schema Types".

2.3 Implementing Application Logic

At this point we have all the parts we need to do something useful with the information stored in our XML document:

```
#include <iostream>

#include "hello.hxx"
#include "hello-pimpl.hxx"

using namespace std;

int
main (int argc, char* argv[])
{
  try
  {
    // Parse.
    //
    hello_paggr hello_p;
    xml_schema::document_pimpl doc_p (hello_p.root_parser (),
                                      hello_p.root_name ());
    hello_p.pre ();
    doc_p.parse (argv[1]);
    hello* h = hello_p.post ();

    // Print what we’ve got.
    //
    for (hello::name_const_iterator i = h->name ().begin ();
         i != h->name ().end ();
         ++i)
    {
      cout << h->greeting () << ", " << *i << "!" << endl;
    }

    delete h;
  }
  catch (const xml_schema::parser_exception& e)
  {
    cerr << argv[1] << ":" << e.line () << ":" << e.column ()
         << ": " << e.text () << endl;
    return 1;
  }
}
```

The first part of our application creates a document parser and parses the XML file specified in the command line to the object model. The `hello_paggr` class is the parser aggregate class we discussed earlier. Parsing is covered in more detail in Chapter 6, "Parsing and Serialization". The second part uses the returned object model to iterate over names and print a greeting line for each of them. We also catch and print the `xml_schema::parser_exception` exception in case something goes wrong.

2.4 Compiling and Running

After saving our application from the previous section in `driver.cxx`, we are ready to compile our first program and run it on the test XML document. On UNIX this can be done with the following commands:

```
$ c++ -I.../libxsde -c driver.cxx hello-pskel.cxx hello-pimpl.cxx
$ c++ -o driver driver.o hello-pskel.o hello-pimpl.o \
  .../libxsde/xsde/libxsde.a
$ ./driver hello.xml
Hello, sun!
Hello, moon!
Hello, world!
```

Here `.../libxsde` represents the path to the `libxsde` directory in the XSD/e distribution.

We can also test the error handling. To test XML well-formedness checking, we can try to parse `hello.hxx`:

```
$ ./driver hello.hxx
hello.hxx:1:0: not well-formed (invalid token)
```

We can also try to parse a valid XML but not from our vocabulary, for example `hello.xsd`:

```
$ ./driver hello.xsd
hello.xsd:2:57: unexpected element encountered
```

2.5 Adding Serialization

While parsing and accessing the XML data may be everything you need, there are applications that require creating new or modifying existing XML documents. To request the generation of serialization support we will need to add the `--generate-serializer` option to our XSD/e compiler invocation:

```
$ xsde cxx-hybrid --generate-parser --generate-serializer \
  --generate-aggregate hello.xsd
```

This will result in two additional pairs of C++ files: `hello-sskel.hxx` and `hello-sskel.cxx`, as well as `hello-simpl.hxx` and `hello-simpl.cxx`. Similar to the parser files, the first pair contains serializer skeletons (generated by the C++/Serializer mapping) and the second pair contains serializer implementations as well as the serializer aggregate for the `hello` root element.

Let us first examine an application that modifies an existing object model and serializes it back to XML:

```
#include <iostream>

#include "hello.hxx"
#include "hello-pimpl.hxx"
#include "hello-simpl.hxx"

using namespace std;

int
main (int argc, char* argv[])
{
  try
  {
    // Parse.
    //
    hello_paggr hello_p;
    xml_schema::document_pimpl doc_p (hello_p.root_parser (),
                                      hello_p.root_name ());
    hello_p.pre ();
    doc_p.parse (argv[1]);
    hello* h = hello_p.post ();

    // Change the greeting phrase.
    //
    h->greeting ("Hi");

    // Add another entry to the name sequence.
    //
    h->name ().push_back ("mars");

    // Serialize the modified object model to XML.
    //
    hello_saggr hello_s;
    xml_schema::document_simpl doc_s (hello_s.root_serializer (),
                                      hello_s.root_name ());
    hello_s.pre (*h);
    doc_s.serialize (cout);
    hello_s.post ();

    delete h;
  }
  catch (const xml_schema::parser_exception& e)
  {
    cerr << argv[1] << ":" << e.line () << ":" << e.column ()
         << ": " << e.text () << endl;
    return 1;
  }
  catch (const xml_schema::serializer_exception& e)
  {
    cerr << "error: " << e.text () << endl;
    return 1;
  }
}
```

First, our application parses an XML document and obtains its object model as in the previous example. Then it changes the greeting string and adds another entry to the list of names. Finally, it creates a document serializer and serializes the object model back to XML. The resulting XML is written to the standard output (`cout`) for us to inspect. We could have also written the result to a file or memory buffer by creating an instance of `std::ofstream` or `std::ostringstream` and passing it to `serialize()` instead of `cout`. The `hello_saggr` class is the serializer aggregate class we discussed earlier. Serialization is covered in more detail in Chapter 6, "Parsing and Serialization".

If we now compile and run this application (don’t forget to compile and link `hello-sskel.cxx` and `hello-simpl.cxx`), we will see the output as shown in the following listing:

```
<hello>
  <greeting>Hi</greeting>
  <name>sun</name>
  <name>earth</name>
  <name>world</name>
  <name>mars</name>
</hello>
```

We can also test XML Schema validation. We can "accidently" remove all the names from the object model by adding the following after: `push_back ("mars")`:

```
h->name ().clear ();
```

This will violate our vocabulary specification which requires at least one `name` element to be present. If we make the above change and recompile our application, we will get the following output:

```
$ ./driver hello.xml
error: expected element not encountered
```

It is also possible to create and serialize an object model from scratch as shown in the following example. For this case we can remove the `--generate-parser` option since we don’t need support for XML parsing.

```
#include <sstream>
#include <iostream>

#include "hello.hxx"
#include "hello-simpl.hxx"

using namespace std;

int
main (int argc, char* argv[])
{
  try
  {
    hello h;
    h.greeting ("Hi");

    hello::name_sequence& ns = h.name ();
    ns.push_back ("Jane");
    ns.push_back ("John");

    // Serialize the object model to XML.
    //
    hello_saggr hello_s;
    xml_schema::document_simpl doc_s (hello_s.root_serializer (),
                                      hello_s.root_name ());
    ostringstream ostr;

    hello_s.pre (*h);
    doc_s.serialize (ostr);
    hello_s.post ();

    delete h;

    cout << ostr.c_str () << endl;
  }
  catch (const xml_schema::serializer_exception& e)
  {
    cerr << "error: " << e.text () << endl;
    return 1;
  }
}
```

In this example we used the generated default constructor to create an empty instance of type `hello`. We then set greeting and, to reduce typing, we obtained a reference to the name sequence which we used to add a few names. The serialization part is identical to the previous example except this time we first save the XML representation into a string. If we compile and run this program, it produces the following output:

```
<hello>
  <greeting>Hi</greeting>
  <name>Jane</name>
  <name>John</name>
</hello>
```

2.6 A Minimal Version

The previous sections showed a number of examples that relied on STL for strings, iostream of input/output and C++ exceptions for error handling. As was mentioned in the introduction and will be discussed in further detail in the next chapter, the C++/Hybrid mapping can be configured only to rely on the minimal subset of C++. In this section we will implement an example that parses, prints, modifies and serializes the object model without relying on STL, iostream, or C++ exceptions.

The first step is to instruct the XSD/e compiler not to use any of the above features in the generated code. You may also need to re-configure and rebuild the XSD/e runtime library (`libxsde.a`) to disable STL, iostream, and exceptions.

```
$ xsde cxx-hybrid --no-stl --no-iostream --no-exceptions \
  --generate-parser --generate-serializer --generate-aggregate \
  hello.xsd
```

If you now study the generated `hello.hxx` file, you will notice that the use of `std::string` type is replaced with `char*`. When STL is disabled, built-in XML Schema type `string` is mapped to a C string. The following listing presents the content of `driver.cxx` in full:

```
#include <stdio.h>

#include "people.hxx"

#include "people-pimpl.hxx"
#include "people-simpl.hxx"

using namespace std;

struct writer: xml_schema::writer
{
  virtual bool
  write (const char* s, size_t n)
  {
    return fwrite (s, n, 1, stdout) == 1;
  }

  virtual bool
  flush ()
  {
    return fflush (stdout) == 0;
  }
};

int
main (int argc, char* argv[])
{
  // Open the file or use STDIN.
  //
  FILE* f = fopen (argv[1], "rb");

  if (f == 0)
  {
    fprintf (stderr, "%s: unable to open\n", argc);
    return 1;
  }

  // Parse.
  //
  using xml_schema::parser_error;

  parser_error pe;
  bool io_error = false;
  hello* h = 0;

  do
  {
    hello_paggr hello_p;
    xml_schema::document_pimpl doc_p (hello_p.root_parser (),
                                      hello_p.root_name ());
    if (pe = doc_p._error ())
      break;

    hello_p.pre ();

    if (pe = hello_p._error ())
      break;

    char buf[4096];

    do
    {
      size_t s = fread (buf, 1, sizeof (buf), f);

      if (s != sizeof (buf) && ferror (f))
      {
        io_error = true;
        break;
      }
      doc_p.parse (buf, s, feof (f) != 0);
      pe = doc_p._error ();

    } while (!pe && !feof (f));

    if (io_error || pe)
      break;

    h = hello_p.post ();
    pe = hello_p._error ();

  } while (false);

  fclose (f);

  // Handle parsing errors.
  //
  if (io_error)
  {
    fprintf (stderr, "%s: read failure\n", argc);
    return 1;
  }

  if (pe)
  {
    switch (pe.type ())
    {
    case parser_error::sys:
      {
        fprintf (stderr, "%s: %s\n", argc, pe.sys_text ());
        break;
      }
    case parser_error::xml:
      {
        fprintf (stderr, "%s:%lu:%lu: %s\n",
                 argc, pe.line (), pe.column (), pe.xml_text ());
        break;
      }
    case parser_error::schema:
      {
        fprintf (stderr, "%s:%lu:%lu: %s\n",
                 argc, pe.line (), pe.column (), pe.schema_text ());
        break;
      }
    default:
      break;
    }

    return 1;
  }
```

```
// Print what we’ve got.
//
for (hello::name_const_iterator i = h->name ().begin ();
     i != h->name ().end ();
     ++i)
{
  printf ("%s, %s!\n", h->greeting (), *i);
}

using xml_schema::strdupx;

// Change the greeting phrase.
//
h->greeting (strdupx ("Hi"));

// Add another entry to the name sequence.
//
h->name ().push_back (strdupx ("mars"));

// Serialize.
//
using xml_schema::serializer_error;

serializer_error se;
writer w;

do
{
  hello_saggr hello_s;
  xml_schema::document_simpl doc_s (hello_s.root_serializer (),
                                    hello_s.root_name ());
  if (se = doc_s._error ())
    break;

  hello_s.pre (*h);

  if (se = hello_s._error ())
    break;

  doc_s.serialize (w);

  if (se = doc_s._error ())
    break;

  hello_s.post ();

  se = hello_s._error ();

} while (false);

delete h;
```

```
  // Handle serializer errors.
  //
  if (se)
  {
    switch (se.type ())
    {
    case serializer_error::sys:
      {
        fprintf (stderr, "error: %s\n", se.sys_text ());
        break;
      }
    case serializer_error::xml:
      {
        fprintf (stderr, "error: %s\n", se.xml_text ());
        break;
      }
    case serializer_error::schema:
      {
        fprintf (stderr, "error: %s\n", se.schema_text ());
        break;
      }
    default:
      break;
    }

    return 1;
  }
}
```

The parsing and serialization parts of the above example got quite a bit more complex due to the lack of exceptions and iostream support. For more information on what’s going on there, refer to Chapter 6, "Parsing and Serialization". On the other hand, the access and modification of the object model stayed relatively unchanged. The only noticeable change is the use of the `xml_schema::strdupx` function to create C strings from string literals. We have to use this function because the object model assumes ownership of the strings passed. We also cannot use the standard C `strdup` because the object model expects the strings to be allocated with C++ operator `new[]` while C `strdup` uses `malloc` (on most implementations operator `new` is implemented in terms of `malloc` so you can probably use `strdup` if you really want to).

3 Mapping Configuration

The Embedded C++/Hybrid mapping has a number of configuration parameters that determine the overall properties and behavior of the generated code, such as the use of Standard Template Library (STL), Input/Output Stream Library (iostream), C++ exceptions, XML Schema validation, 64-bit integer types, as well as parser and serializer implementation reuse styles. In the previous chapter we have already got an overview of the changes to the generated code that happen when we disable STL, iostream, and C++ exceptions. In this chapter we will discuss these and other configuration parameters in more detail.

In order to enable or disable a particular feature, the corresponding configuration parameter should be set accordingly in the XSD/e runtime library as well as specified during schema compilation with the XSD/e command line options as described in the XSD/e Compiler Command Line Manual.

While the XML documents can use various encodings, the Embedded C++/Hybrid mapping always delivers character data to the application in the UTF-8 encoding. The underlying XML parser used by the mapping includes built-in support for XML documents encoded in UTF-8, UTF-16, ISO-8859-1, and US-ASCII. Other encodings can be supported by providing application-specific decoder functions. C++/Hybrid also expects character data supplied by the application to be in the UTF-8 encoding. The underlying XML serializer used by the mapping produces the resulting XML in the UTF-8 encoding as well.

3.1 Standard Template Library

To disable the use of STL you will need to configure the XSD/e runtime without support for STL as well as pass the `--no-stl` option to the XSD/e compiler when translating your schemas.

When STL is disabled, all string-based XML Schema types (see Chapter 5, "Mapping for Built-In XML Schema Types") are mapped to C-style `char*` instead of `std::string`. In this configuration when you set an element or attribute value of a string-based type, the object model assumes ownership of the string and expects that it was allocated with operator `new[]`. To simplify creation of such strings from string literals, the generated code provides the `strdupx` and `strndupx` functions in the `xml_schema` namespace. These functions are similar to C `strdup` and `strndup` except that they use operator `new[]` instead of `malloc` to allocate the string:

```
namespace xml_schema
{
  char*
  strdupx (const char*);

  char*
  strndupx (const char*, size_t);
}
```

3.2 Input/Output Stream Library

To disable the use of iostream you will need to configure the XSD/e runtime library without support for iostream as well as pass the `--no-iostream` option to the XSD/e compiler when translating your schemas. When iostream is disabled, a number of overloaded `parse()` and `serialize()` functions in the document parser (`xml_schema::document_pimpl`) and document serializer (`xml_schema::document_simpl`) become unavailable. See Chapter 7, "Document Parser and Error Handling" in the Embedded C++/Parser Mapping Getting Started Guide and Chapter 8, "Document Serializer and Error Handling" in the Embedded C++/Serializer Mapping Getting Started Guide for details.

3.3 C++ Exceptions

To disable the use of C++ exceptions, you will need to configure the XSD/e runtime without support for exceptions as well as pass the `--no-exceptions` option to the XSD/e compiler when translating your schemas. When C++ exceptions are disabled, the error conditions that may arise while parsing, serializing, and modifying the object model are indicated with error codes instead of exceptions. For more information on error handling during parsing, see Chapter 7, "Document Parser and Error Handling" in the Embedded C++/Parser Mapping Getting Started Guide. For more information on error handling during serialization, see Chapter 8, "Document Serializer and Error Handling" in the Embedded C++/Serializer Mapping Getting Started Guide. For more information on error handling in the object model, see Chapter 4, "Working with Object Models" below.

3.4 XML Schema Validation

By default, XML Schema validation is enabled during both parsing and serialization. To disable validation during parsing, you will need to configure the XSD/e runtime to disable support for validation in the C++/Parser mapping as well as pass the `--suppress-parser-val` option to the XSD/e compiler when translating your schemas. To disable validation during serialization, you will need to configure the XSD/e runtime to disable support for validation in the C++/Serializer mapping as well as pass the `--suppress-serializer-val` option to the XSD/e compiler when translating your schemas. If you are disabling validation during both parsing and serialization, you can use the `--suppress-validation` option instead of the two options mentioned above.

Disabling XML Schema validation allows to further increase the parsing and serialization performance as well as reduce footprint in cases where the data being parsed and/or serialized is known to be valid.

3.5 64-bit Integer Type

By default the 64-bit `long` and `unsignedLong` built-in XML Schema types are mapped to the 64-bit `long long` and `unsigned long long` fundamental C++ types. To disable the use of these types in the mapping you will need to configure the XSD/e runtime accordingly as well as pass the `--no-long-long` option to the XSD/e compiler when translating your schemas. When the use of 64-bit integral C++ types is disabled the `long` and `unsignedLong` XML

Schema built-in types are mapped to `long` and `unsigned long` fundamental C++ types.

3.6 Parser and Serializer Reuse

When one type in XML Schema inherits from another, it is often desirable to be able to reuse the parser and serializer implementations corresponding to the base type in the parser and serializer implementations corresponding to the derived type. XSD/e provides support for two reuse styles: the so-called *mixin* (generated when the `--reuse-style-mixin` option is specified) and *tiein* (generated by default) styles. The XSD/e runtime should be configured in accordance with the reuse style used in the generated code. See Section 5.6, "Parser Reuse" in the Embedded C++/Parser Mapping Getting Started Guide and Section 6.6, "Serializer Reuse" in the Embedded C++/Serializer Mapping Getting Started Guide for details.

4 Working with Object Models

As we have seen in the previous chapters, the XSD/e compiler generates a C++ class for each type defined in XML Schema. Together these classes constitute an object model for an XML vocabulary. In this chapter we will take a closer look at different parts that comprise an object model class as well as how to create, access, and modify object models.

In this chapter we will use the following schema that describes a collection of person records. We save it in `people.xsd`:

```
<?xml version="1.0"?>
<xs:schema xmlns:xs="http://www.w3.org/2001/XMLSchema">

  <xs:simpleType name="gender">
    <xs:restriction base="xs:string">
      <xs:enumeration value="male"/>
      <xs:enumeration value="female"/>
    </xs:restriction>
  </xs:simpleType>

  <xs:complexType name="person">
    <xs:sequence>
      <xs:element name="first-name" type="xs:string"/>
      <xs:element name="middle-name" type="xs:string" minOccurs="0"/>
      <xs:element name="last-name" type="xs:string"/>
      <xs:element name="gender" type="gender"/>
      <xs:element name="age" type="xs:unsignedShort"/>
    </xs:sequence>
    <xs:attribute name="id" type="xs:unsignedInt" use="required"/>
  </xs:complexType>

  <xs:complexType name="people">
    <xs:sequence>
```

```
      <xs:element name="person" type="person" maxOccurs="unbounded"/>
    </xs:sequence>
  </xs:complexType>

  <xs:element name="people" type="people"/>

</xs:schema>
```

A sample XML instance to go along with this schema is saved in `people.xml`:

```
<?xml version="1.0"?>
<people>

  <person id="1">
    <first-name>John</first-name>
    <last-name>Doe</last-name>
    <gender>male</gender>
    <age>32</age>
  </person>

  <person id="2">
    <first-name>Jane</first-name>
    <middle-name>Mary</middle-name>
    <last-name>Doe</last-name>
    <gender>female</gender>
    <age>28</age>
  </person>

</people>
```

Compiling `people.xsd` with the XSD/e compiler results in three generated object model classes: `gender`, `person` and `people`. Here is how they look with STL enabled:

```
// gender (fixed-length)
//
class gender: public std::string
{
public:
  gender ();
  gender (const gender&);
  gender& operator= (const gender&);
};

// person (fixed-length)
//
class person
{
public:
  person ();
  person (const person&);
  person& operator= (const person&);
```

```
// id
//
unsigned int
id () const;

unsigned int&
id ();

void
id (unsigned int);

// first-name
//
const std::string&
first_name () const;

std::string&
first_name ();

void
first_name (const std::string&);

// middle-name
//
bool
middle_name_present () const;

void
middle_name_present (bool);

const std::string&
middle_name () const;

std::string&
middle_name ();

void
middle_name (const std::string&);

// last-name
//
const std::string&
last_name () const;

std::string&
last_name ();

void
last_name (const std::string&);
```

```
  // gender
  //
  const ::gender&
  gender () const;

  ::gender&
  gender ();

  void
  gender (const ::gender&);

  // age
  //
  unsigned short
  age () const;

  unsigned short&
  age ();

  void
  age (unsigned short);

private:
  ...
};

// people (variable-length)
//
class people
{
public:
  people ();

private:
  people (const people&);
  people& operator= (const people&);

public:
  // person
  //
  typedef xsde::fix_sequence<person> person_sequence;
  typedef person_sequence::iterator person_iterator;
  typedef person_sequence::const_iterator person_const_iterator;

  const person_sequence&
  person () const;

  person_sequence&
  person ();
```

```
private:
  ...
};
```

We will examine these classes in detail in the subsequent sections.

4.1 Namespaces

XSD/e maps XML namespaces specified in the `targetNamespace` attribute in XML Schema to one or more nested C++ namespaces. By default, a namespace URI is mapped to a sequence of C++ namespace names by removing the protocol and host parts and splitting the rest into a sequence of names with `'/'` as the name separator. For example, the `http://www.codesynthesis.com/cs/my` XML namespace is mapped to the `cs::my` C++ namespace.

The default mapping of namespace URIs to C++ namespaces can be altered using the `--namespace-map` and `--namespace-regex` compiler options. For example, to map the `http://www.codesynthesis.com/my` XML namespace to the `cs::my` C++ namespace, we can use the following option:

```
--namespace-map http://www.codesynthesis.com/my=cs::my
```

A vocabulary without a namespace is mapped to the global scope. This also can be altered with the above options by using an empty name for the XML namespace. For example, we could place the generated object model classes for the `people.xsd` schema into the `records` C++ namespace by adding the following option:

```
--namespace-map =records
```

4.2 Memory Management

To ensure that objects are allocated and passed efficiently, the C++/Hybrid mapping divides all object model types into fixed-length and variable-length. A type is variable-length if any of the following is true:

1. it is an XML Schema `list` type
2. it is an XML Schema `union` type and STL is disabled
3. it derives from a variable-length type
4. it contains an element or attribute of a variable-length type
5. it contains an element or compositor (`sequence` or `choice`) with `maxOccurs` greater than one
6. it is recursive (that is, one of its elements contains a reference, directly or indirectly, to the type itself)

The following build-in XML Schema types are variable-length: `base64Binary`, `hexBinary`, `NMTOKENS`, and `IDREFS`. Furthermore, if STL is disabled, all string-based build-in XML Schema types are variable-length, namely: `string`, `normalizedString`, `token`, `Name`, `NMTOKEN`, `NCName`, `language`, `QName`, `ID`, `IDFER`, and `anyURI`.

Otherwise, a type is fixed-length. As you might have noticed from the previous code listings, the XSD/e compiler adds a comment before each generated object model class that states whether it is fixed or variable-length. For example, the `people` type is variable-length because it contains a sequence of `person` elements (`maxOccurs="unbounded"`). If we recompile the `people.xsd` schema with the `--no-stl` option, the first two types will also become variable-length since `gender` inherits from and `person` contains elements of the `string` built-in type. And when STL is disabled, `string` is variable-length.

The object model uses different methods for storing and passing around fixed-length and variable-length types. Instances of fixed-length types are stored and passed by value since it is cheaper to copy than to allocate them dynamically (in the STL case, the `std::string` is expected to support the referenced-counted copy-on-write optimization, which makes copying cheap).

Variable-length types are always allocated dynamically and are stored and passed as pointers. Because copying an instance of a variable-length type can be expensive, such types make their copy constructor and copy assignment operators unavailable.

When you set a value of an element or attribute of a variable-length type, the object model assumes ownership of the pointed to object. It expects you to allocate the object with operator `new` and will eventually delete it with operator `delete`. As an example, let us extend our `people.xsd` schema with the following type:

```
<xs:complexType name="staff">
  <xs:sequence>
    <xs:element name="permanent" type="people"/>
    <xs:element name="contract" type="people"/>
  </xs:sequence>
</xs:complexType>
```

If we compile it with XSD/e, we will get the following C++ class:

```
// staff (variable-length)
//
class staff
{
public:
  staff ();

private:
  staff (const staff&);
  staff& operator= (const staff&);
public:
  // permanent
  //
  const people&
  permanent () const;

  people&
  permanent ();

  void
  permanent (people*);

  // contract
  //
  const people&
  contract () const;

  people&
  contract ();

  void
  contract (people*);

private:
  ...
};
```

Notice that unlike, say, the `first_name()` modifier function in the `person` class, the `permanent()` and `contract()` modifiers expect a pointer to the `people` object. The following listing shows how we can create and populate an instance of the `staff` class. The use of smart pointers to hold the results of dynamic allocations is omitted for brevity:

```
people* per = new people;
people* con = new people;

// Populate per and con.

staff s;
s->permanent (per) // Assumes ownership or per.
s->contract (con)  // Assumes ownership or con.
```

4.3 Attributes and Elements

As we have seen before, XSD/e generates a different set of member functions for elements with different cardinalities. The C++/Hybrid mapping divides all the possible element and attribute cardinalities into three cardinality classes: *one*, *optional*, and *sequence*.

The *one* cardinality class covers all elements that should occur exactly once as well as the required attributes. In our example, the `first-name`, `last-name`, `gender`, and `age` elements as well as the `id` attribute belong to this cardinality class. The following code fragment shows again the accessor and modifier functions that are generated for the `first-name` element in the `person` class:

```
class person
{
  // first-name
  //
  const std::string&
  first_name () const;

  std::string&
  first_name ();

  void
  first_name (const std::string&);
};
```

The first two accessor functions return read-only (constant) and read-write references to the element's value, respectively. The modifier function sets the new value for the element. Note that the signature of the modifier function varies depending on whether the element or attribute is of a fixed or variable-length type, as was discussed in the previous section.

The *optional* cardinality class covers all elements that can occur zero or one time as well as optional attributes. In our example, the `middle-name` element belongs to this cardinality class. The following code fragment shows again the accessor and modifier functions that are generated for this element in the `person` class:

```
class person
{
  // middle-name
  //
  bool
  middle_name_present () const;

  void
  middle_name_present (bool);

  const std::string&
  middle_name () const;

  std::string&
  middle_name ();

  void
  middle_name (const std::string&);
};
```

Compared to the *one* cardinality class, *optional* adds two extra functions for querying and modifying the element's presence status. The following example shows how we can use these functions:

```
person& p = ...

if (p.middle_name_present ())
{
  cout << p.middle_name () << endl;
  p.middle_name_present (false); // Reset to the "not present" state.
}
```

Finally, the *sequence* cardinality class covers all elements that can occur more than once. In our example, the `person` element in the `people` type belongs to this cardinality class. The following code fragment shows again the type definitions as well as the accessor and modifier functions that are generated for this element in the `people` class:

```
class people
{
  // person
  //
  typedef xsde::fix_sequence<person> person_sequence;
  typedef person_sequence::iterator person_iterator;
  typedef person_sequence::const_iterator person_const_iterator;

  const person_sequence&
  person () const;

  person_sequence&
  person ();
};
```

The `person_sequence` type is a sequence container for the element's values. It has an interface similar to `std::vector` and we will discuss it in more detail shortly. The `person_iterator` and `person_const_iterator` types are read-write and read-only (constant) iterators for the `person_sequence` container.

Unlike other two cardinality classes, the *sequence* class only provides accessor functions that return read-only (constant) and read-write references to the sequence container. The modification of the element values is performed my manipulating the returned sequence container and elements that it contains.

In the remainder of this section we will examine the interfaces of the sequence containers which differ slightly depending on whether the element type is fixed or variable-length and whether C++ exceptions are enabled. Also, when STL is disabled, string sequences have a special interface which is also discussed below.

When exceptions are enabled, the fixed-length type sequences are implemented in terms of the following class template:

```
template <typename T>
class fix_sequence
{
public:
  typedef T         value_type;
  typedef T*        pointer;
  typedef const T*  const_pointer;
  typedef T&        reference;
  typedef const T&  const_reference;

  typedef size_t    size_type;
  typedef ptrdiff_t difference_type;

  typedef T*        iterator;
  typedef const T*  const_iterator;

public:
  fix_sequence ();

  void
  swap (fix_sequence&);

private:
  fix_sequence (const fix_sequence&);

  fix_sequence&
  operator= (fix_sequence&);

public:
  iterator
  begin ();

  const_iterator
  begin () const;

  iterator
  end ();

  const_iterator
  end () const;

  T&
  front ();

  const T&
  front () const;

  T&
  back ();

  const T&
  back () const;

  T&
  operator[] (size_t);

  const T&
  operator[] (size_t) const;

public:
  bool
  empty () const;

  size_t
  size () const;

  size_t
  capacity () const;

  size_t
  max_size () const;

public:
  void
  clear ();

  void
  pop_back ();

  iterator
  erase (iterator);

  void
  push_back (const T&);

  iterator
  insert (iterator, const T&);

  void
  reserve (size_t);
};
```

When C++ exceptions are disabled, the signatures of the `push_back()`, `insert()`, and `reserve()` functions change as follows:

```
template <typename T>
class fix_sequence
{
public:
  enum error
  {
    error_none,
    error_no_memory
  };

  ...

public:
  error
  push_back (const T&);

  error
  insert (iterator, const T&);

  error
  insert (iterator, const T&, iterator& result);

  error
  reserve (size_t);
};
```

That is, the functions that may require memory allocation now return an error code that you will need to check in order to detect the out of memory condition.

When exceptions are enabled, the variable-length type sequences are implemented in terms of the following class template:

```
template <typename T>
class var_sequence
{
public:
  typedef T         value_type;
  typedef T*        pointer;
  typedef const T*  const_pointer;
  typedef T&        reference;
  typedef const T&  const_reference;

  typedef size_t    size_type;
  typedef ptrdiff_t difference_type;

  typedef <implementation details> iterator;
  typedef <implementation details> const_iterator;

public:
  var_sequence ();

  void
  swap (var_sequence&);
```

```
private:
  var_sequence (const var_sequence&);

  var_sequence&
  operator= (var_sequence&);

public:
  iterator
  begin ();

  const_iterator
  begin () const;

  iterator
  end ();

  const_iterator
  end () const;

  T&
  front ();

  const T&
  front () const;

  T&
  back ();

  const T&
  back () const;

  T&
  operator[] (size_t);

  const T&
  operator[] (size_t) const;

public:
  bool
  empty () const;

  size_t
  size () const;

  size_t
  capacity () const;

  size_t
  max_size () const;

public:
  void
  clear ();

  void
  pop_back ();

  iterator
  erase (iterator);

  void
  push_back (T*);

  iterator
  insert (iterator, T*);

  error
  reserve (size_t);
};
```

Most of this interface is identical to the fixed-length type version except for the `push_back()` and `insert()` functions. Similar to the modifier functions for elements and attributes of variable-length types, these two functions expect a pointer to the dynamically-allocated instance of the type and assume ownership of the passed object. To simplify error handling, these two functions delete the passed object if the reallocation of the underlying sequence buffer fails.

When C++ exceptions are disabled, the `push_back()`, `insert()`, and `reserve()` functions return an error code to signal the out of memory condition:

```
template <typename T>
class var_sequence
{
public:
  enum error
  {
    error_none,
    error_no_memory
  };

  ...

public:
  error
  push_back (T*);

  error
  insert (iterator, T*);

  error
  insert (iterator, T*, iterator& result);
  error
  reserve (size_t);
};
```

When STL is enabled, the string sequence have the same interface as `fix_sequence<std::string>`. When STL is disabled and strings are mapped to `char*`, the string sequence has a special interface. When C++ exceptions are enabled, it has the following definition:

```
namespace xml_schema
{
  class string_sequence
  {
  public:
    typedef char*         value_type;
    typedef char**        pointer;
    typedef const char**  const_pointer;
    typedef char*         reference;
    typedef const char*   const_reference;

    typedef size_t        size_type;
    typedef ptrdiff_t     difference_type;

    typedef char** iterator;
    typedef const char* const* const_iterator;

    string_sequence ();

    void
    swap (string_sequence&);

  private:
    string_sequence (string_sequence&);

    string_sequence&
    operator= (string_sequence&);

  public:
    iterator
    begin ();

    const_iterator
    begin () const;

    iterator
    end ();

    const_iterator
    end () const;
    char*
    front ();

    const char*
    front () const;

    char*
    back ();

    const char*
    back () const;

    char*
    operator[] (size_t);

    const char*
    operator[] (size_t) const;

  public:
    bool
    empty () const;

    size_t
    size () const;

    size_t
    capacity () const;

    size_t
    max_size () const;

  public:
    void
    clear ();

    void
    pop_back ();

    iterator
    erase (iterator);

    void
    push_back (char*);

    void
    push_back_copy (const char*);

    iterator
    insert (iterator, char*);
    void
    reserve (size_t);

    // Detach a string from the sequence at a given position.
    // The string pointer at this position in the sequence is
    // set to 0.
    //
    char*
    detach (iterator);
  };
}
```

The `push_back()` and `insert()` functions assume ownership of the passed string which should be allocated with operator `new[]` and will be deallocated with operator `delete[]` by the `string_sequence` object. Similar to `var_sequence`, these two functions free the passed string if the reallocation of the underlying sequence buffer fails. The `push_back_copy()` function makes a copy of the passed string. If you detach the underlying element string, then it should eventually be deallocated with operator `delete[]`.

When C++ exceptions are disabled, the signatures of the `push_back()`, `push_back_copy()`, `insert()`, and `reserve()` functions in the `string_sequence` class change as follows:

```
namespace xml_schema
{
  class string_sequence
  {
  public:
    enum error
    {
      error_none,
      error_no_memory
    };

    ...

  public:
    error
    push_back (char*);

    error
    push_back_copy (const char*);

    error
    insert (iterator, char*);

    error
    insert (iterator, char*, iterator& result);
    error
    reserve (size_t);
  };
}
```

4.4 Compositors

The XML Schema language provides three compositor constructs that are used to group elements: `all`, `sequence`, and `choice`. If a compositor has an *optional* or *sequence* cardinality class (see Section 4.3, "Attributes and Elements") or if a compositor is inside `choice`, then the C++/Hybrid mapping generates a nested class for such a compositor as well as a set of accessor and modifier functions similar to the ones defined for elements and attributes. Otherwise, the member functions, corresponding to elements defined in a compositor, are generated directly in the containing class.

Compositor classes are either fixed or variable-length and obey the same storage and passing rules as object model classes corresponding to XML Schema types (see Section 4.2, "Memory Management"). Consider the following schema fragment as an example:

```
<complexType name="type">
  <sequence>
    <sequence minOccurs="0">
      <element name="a" type="int"/>
      <element name="b" type="string" maxOccurs="unbounded"/>
    </sequence>
    <sequence maxOccurs="unbounded">
      <element name="c" type="int"/>
      <element name="d" type="string"/>
    </sequence>
  </sequence>
</complexType>
```

The corresponding object model class is shown below:

```
// type (variable-length)
//
class type
{
public:
  type ();

private:
  type (const type&);
  type& operator= (const type&);

public:
  // sequence (variable-length)
  //
```

```
class sequence_type
{
public:
  sequence_type ();

private:
  sequence_type (const sequence_type&);
  sequence_type& operator= (const sequence_type&);

public:
  // a
  //
  int
  a () const;

  int&
  a ();

  void
  a (int);

  // b
  //
  typedef xsde::string_sequence b_sequence;
  typedef b_sequence::iterator b_iterator;
  typedef b_sequence::const_iterator b_const_iterator;

  const b_sequence&
  b () const;

  b_sequence&
  b ();

private:
  ...
};

bool
sequence_present () const;

void
sequence_present (bool);

const sequence_type&
sequence () const;

sequence_type&
sequence ();

void
sequence (sequence_type*);
```

```
  // sequence1 (fixed-length)
  //
  class sequence1_type
  {
  public:
    sequence1_type ();
    sequence1_type (const sequence1_type&);
    sequence1_type& operator= (const sequence1_type&);

    // c
    //
    int
    c () const;

    int&
    c ();

    void
    c (int);

    // d
    //
    const std::string&
    d () const;

    std::string&
    d ();

    void
    d (const std::string&);

  private:
    ...
  };

  typedef xsde::fix_sequence<sequence1_type> sequence1_sequence;
  typedef sequence1_sequence::iterator sequence1_iterator;
  typedef sequence1_sequence::const_iterator sequence1_const_iterator;

  const sequence1_sequence&
  sequence1 () const;

  sequence1_sequence&
  sequence1 ();

private:
  ...
};
```

The content of the outer `sequence` compositor is generated in-line since this compositor belongs to the *one* cardinality class. The first nested `sequence` compositor is optional (`minOccurs="0"`), which results in a corresponding nested class. Notice that the `sequence_type` is variable-length and the accessor and modifier functions corresponding to this `sequence` compositor are the same as for an optional element or attribute. Similarly, the second nested compositor is of the *sequence* cardinality class (`maxOccurs="unbounded"`), which also results in a nested class and a set of accessor functions.

Generated code corresponding to an `all` and `sequence` compositor, whether in-line or as a nested class, simply define accessor and modifier functions for the elements that this compositor contains. For the `choice` compositor, on the other hand, additional types and functions are generated to support querying and selecting the choice arm that is in effect. Consider the following simple example:

```
<complexType name="type">
  <choice>
    <element name="a" type="int"/>
    <element name="b" type="string"/>
    <element name="c" type="boolean"/>
  </choice>
</complexType>
```

The corresponding object model class is shown next:

```
// type (fixed-length)
//
class type
{
public:
  type ();
  type (const type&);
  type& operator= (const type&);

  // choice
  //
  enum choice_arm_tag
  {
    a_tag,
    b_tag,
    c_tag
  };

  choice_arm_tag
  choice_arm () const;

  void
  choice_arm (choice_arm_tag);

  // a
  //
  int
  a () const;

  int&
  a ();

  void
  a (int);

  // b
  //
  const std::string&
  b () const;

  std::string&
  b ();

  void
  b (const std::string&);

  // c
  //
  bool
  c () const;

  bool&
  c ();

  void
  c (bool);

private:
  ...
};
```

The extra type is the `choice_arm_tag` enumeration which defines a set of tags corresponding to each choice arm. There are also the `choice_arm()` accessor and modifier functions that can be used to query and set the current choice arm. The following code fragment shows how we can use this class:

```
type& x = ...

switch (x.choice_arm ())
{
case type::a_tag:
  {
    cout << "a: " << x.a () << endl;
    break;
  }
case type::b_tag:
  {
    cout << "b: " << x.b () << endl;
    break;
  }
case type::c_tag:
  {
    cout << "c: " << x.c () << endl;
    break;
  }
}

// Modifiers automatically set the corresponding arm.
//
x.a (10);

// For accessors we need to select the arm explicitly.
//
x.choice_arm (type::b_tag);
x.b () = "b";
```

The following slightly more complex example triggers the generation of nested classes for the `choice` compositor as well as for the `sequence` compositor inside `choice`. Notice that the nested class for `sequence` is generated because it is in `choice` even though its cardinality class is *one*.

```
<complexType name="type">
  <choice maxOccurs="unbounded">
    <sequence>
      <element name="a" type="int"/>
      <element name="b" type="string"/>
    </sequence>
    <element name="c" type="boolean"/>
  </choice>
</complexType>
```

The corresponding object model class is shown next:

```
// type (variable-length)
//
class type
{
public:
  type ();

private:
  type (const type&);
  type& operator= (const type&);

public:
```

```
// choice (fixed-length)
//
class choice_type
{
public:
  choice_type ();
  choice_type (const choice_type&);
  choice_type& operator= (const choice_type&);

  enum choice_arm_tag
  {
    sequence_tag,
    c_tag
  };

  choice_arm_tag
  choice_arm () const;

  void
  choice_arm (choice_arm_tag);

  // sequence (fixed-length)
  //
  class sequence_type
  {
  public:
    sequence_type ();
    sequence_type (const sequence_type&);
    sequence_type& operator= (const sequence_type&);

    // a
    //
    int
    a () const;

    int&
    a ();

    void
    a (int);

    // b
    //
    const std::string&
    b () const;

    std::string&
    b ();

    void
    b (const std::string&);
    private:
      ...
    };

    const sequence_type&
    sequence () const;

    sequence_type&
    sequence ();

    void
    sequence (const sequence_type&);

    // c
    //
    bool
    c () const;

    bool&
    c ();

    void
    c (bool);

  private:
    ...
  };

  typedef xsde::fix_sequence<choice_type> choice_sequence;
  typedef choice_sequence::iterator choice_iterator;
  typedef choice_sequence::const_iterator choice_const_iterator;

  const choice_sequence&
  choice () const;

  choice_sequence&
  choice ();

private:
  ...
};
```

4.5 Accessing the Object Model

In this section we will examine how to get to the information stored in the object model for the person records vocabulary introduced at the beginning of this chapter. The following application accesses and prints the contents of the `people.xml` file:

```
#include <memory>
#include <iostream>

#include "people.hxx"
#include "people-pimpl.hxx"

using namespace std;

int
main ()
{
  // Parse.
  //
  people_paggr people_p;
  xml_schema::document_pimpl doc_p (people_p.root_parser (),
                                    people_p.root_name ());
  people_p.pre ();
  doc_p.parse ("people.xml");
  auto_ptr<people> ppl (people_p.post ());

  // Iterate over individual person records.
  //
  people::person_sequence& ps = ppl->person ();

  for (people::person_iterator i = ps.begin (); i != ps.end (); ++i)
  {
    person& p = *i;

    // Print names: first-name and last-name are required elements,
    // middle-name is optional.
    //
    cout << "name:   " << p.first_name () << " ";

    if (p.middle_name_present ())
      cout << p.middle_name () << " ";

    cout << p.last_name () << endl;

    // Print gender, age, and id which are all required.
    //
    cout << "gender: " << p.gender () << endl
         << "age:    " << p.age () << endl
         << "id:     " << p.id () << endl
         << endl;
  }
}
```

This code shows common patterns of accessing elements and attributes with different cardinality classes. For the sequence element (`person` in the `people` type) we first obtain a reference to the container and then iterate over individual records. The values of elements and attributes with the *one* cardinality class (`first-name`, `last-name`, `gender`, `age`, and `id`) can be obtained directly by calling the corresponding accessor functions. For the optional `middle-name` element we first check if the value is present and only then call the corresponding accessor to retrieve it.

Note that when we want to reduce typing by creating a variable representing a fragment of the object model that we are currently working with (`ps` and `p` above), we obtain a reference to that fragment instead of making a copy. This is generally a good rule to follow when creating efficient applications.

If we run the above application on our sample `people.xml`, the output looks as follows:

```
name:   John Doe
gender: male
age:    32
id:     1

name:   Jane Mary Doe
gender: female
age:    28
id:     2
```

4.6 Modifying the Object Model

In this section we will examine how to modify the information stored in the object model for our person records vocabulary. The following application changes the contents of the `people.xml` file:

```
#include <memory>
#include <iostream>

#include "people.hxx"
#include "people-pimpl.hxx"
#include "people-simpl.hxx"

using namespace std;

int
main ()
{
  // Parse.
  //
  people_paggr people_p;
  xml_schema::document_pimpl doc_p (people_p.root_parser (),
                                    people_p.root_name ());
  people_p.pre ();
  doc_p.parse ("people.xml");
  auto_ptr<people> ppl (people_p.post ());
  // Iterate over individual person records and increment
  // the age.
  //
  people::person_sequence& ps = ppl->person ();

  for (people::person_iterator i = ps.begin (); i != ps.end (); ++i)
  {
    i->age ()++; // Alternative way: i->age (i->age () + 1)
  }

  // Add middle-name to the first record and remove it from
  // the second.
  //
  person& john = ps[0];
  person& jane = ps[1];

  john.middle_name ("Mary");
  jane.middle_name_present (false);

  // Add another John record.
  //
  ps.push_back (john);

  // Serialize the modified object model to XML.
  //
  people_saggr people_s;
  xml_schema::document_simpl doc_s (people_s.root_serializer (),
                                    people_s.root_name ());
  people_s.pre (*ppl);
  doc_s.serialize (cout);
  people_s.post ();
}
```

The first modification the above application performs is iterating over person records and incrementing the age value. This code fragment shows how to modify the value of a required attribute or element. The next modification shows how to set a new value for the optional `middle-name` element as well as clear its value. Finally, the example adds a copy of the John Doe record to the `person` element sequence.

Note that in this case using references for the `ps`, `john`, and `jane` variables is no longer a performance improvement but a requirement for the application to function correctly. If we hadn't used references, all our changes would have been made on copies without affecting the object model.

If we run the above application on our sample `people.xml`, the output looks as follows:

```
<?xml version="1.0"?>
<people>

  <person id="1">
    <first-name>John</first-name>
    <middle-name>Mary</middle-name>
    <last-name>Doe</last-name>
    <gender>male</gender>
    <age>33</age>
  </person>

  <person id="2">
    <first-name>Jane</first-name>
    <last-name>Doe</last-name>
    <gender>female</gender>
    <age>29</age>
  </person>

  <person id="1">
    <first-name>John</first-name>
    <middle-name>Mary</middle-name>
    <last-name>Doe</last-name>
    <gender>male</gender>
    <age>33</age>
  </person>

</people>
```

4.7 Creating the Object Model from Scratch

In this section we will examine how to create a new object model for our person records vocabulary. The following application recreates the content of the original `people.xml` file:

```
#include <iostream>

#include "people.hxx"
#include "people-simpl.hxx"

using namespace std;

int
main ()
{
  people ppl;
  people::person_sequence& ps = ppl.person ();

  // John
  //
  {
    person p;
    p.first_name ("John");
    p.last_name ("Doe");
    p.age (32);
    p.id (1);

    gender g;
    g.assign ("male");
    p.gender (g);

    ps.push_back (p);
  }

  // Jane
  //
  {
    person p;
    p.first_name ("Jane");
    p.middle_name ("Mary");
    p.last_name ("Doe");
    p.age (28);
    p.id (2);

    gender g;
    g.assign ("male");
    p.gender (g);

    ps.push_back (p);
  }

  // Serialize the object model to XML.
  //
  people_saggr people_s;
  xml_schema::document_simpl doc_s (people_s.root_serializer (),
                                    people_s.root_name ());
  people_s.pre (ppl);
  doc_s.serialize (cout);
  people_s.post ();
}
```

The only new part in the above application is the calls to the `people` and `person` constructors. As a general rule, a newly created instance does not assign any values to its elements and attributes. That is, members with the *one* cardinality class are left uninitialized, members with the *optional* cardinality class are set to the "not present" state, and members with the *sequence* cardinality class have empty containers. After the instance has been created, we can set its element and attribute values using the modifier functions.

The above application produces the following output:

```
<?xml version="1.0" ?>
<people>

  <person id="1">
    <first-name>John</first-name>
    <last-name>Doe</last-name>
    <gender>male</gender>
    <age>32</age>
  </person>

  <person id="2">
    <first-name>Jane</first-name>
    <middle-name>Mary</middle-name>
    <last-name>Doe</last-name>
    <gender>female</gender>
    <age>28</age>
  </person>

</people>
```

4.8 Customizing the Object Model

Sometimes it is desirable to be able to store extra, application-specific data in some object model classes or nested compositor classes. Cases where this functionality may be required include handling of typeless content matched by XML Schema wildcards as well as a need for an application to pass extra data as part of the object model. The C++/Hybrid mapping provides a light-weight mechanism for storing custom data by allowing you to add a sequence of opaque objects, stored as `void*`, to select generated classes. It is also possible to customize the parsing and serialization code for such classes in order to populate the custom data sequence during parsing and later serialize it to XML. See Section 6.1, "Customizing Parsers and Serializers" for details.

To instruct the XSD/e compiler to include custom data in a specific object model class, we need to use the `--custom-data` option with the corresponding XML Schema type name as its argument. To include custom data into a nested compositor class, use its qualified name starting with the XML Schema type, for example `type::sequence1`. If we would like to add the ability to store custom data in the generated `person` class for our person records vocabulary, we can compile `people.xsd` like this:

```
$ xsde cxx-hybrid --custom-type person people.xsd
```

The resulting `person` class will have the following extra set of type definitions and functions:

```
// person (variable-length)
//
class person
{
```

```
public:

  ...

  // Custom data.
  //
  typedef xsde::data_sequence custom_data_sequence;
  typedef custom_data_sequence::iterator custom_data_iterator;
  typedef custom_data_sequence::const_iterator custom_data_const_iterator;

  const custom_data_sequence&
  custom_data () const;

  custom_data_sequence&
  custom_data ();
};
```

Notice also that the `person` class is now variable-length since it contains a sequence. When C++ exceptions are enabled, the custom data sequence has the following interface:

```
class data_sequence
{
public:
  typedef void*         value_type;
  typedef void**        pointer;
  typedef const void**  const_pointer;
  typedef void*         reference;
  typedef const void*   const_reference;

  typedef size_t        size_type;
  typedef ptrdiff_t     difference_type;

  typedef void** iterator;
  typedef const void* const* const_iterator;

  typedef void (*destroy_func) (void* data, size_t pos);

public:
  data_sequence ();

  void
  destructor (destroy_func);

  void
  swap (data_sequence&);

private:
  data_sequence (const data_sequence&);

  data_sequence&
  operator= (data_sequence&);
```

```
public:
  iterator
  begin ();

  const_iterator
  begin () const;

  iterator
  end ();

  const_iterator
  end () const;

  void*
  front ();

  const void*
  front () const;

  void*
  back ();

  const void*
  back () const;

  void*
  operator[] (size_t);

  const void*
  operator[] (size_t) const;

public:
  bool
  empty () const;

  size_t
  size () const;

  size_t
  capacity () const;

  size_t
  max_size () const;

public:
  void
  clear ();

  void
  pop_back ();
  iterator
  erase (iterator);

  void
  push_back (void*);

  iterator
  insert (iterator, void*);

  void
  reserve (size_t);
};
```

The `destructor()` modifier allows you to specify the clean up function used to free the sequence elements. The second argument in this clean up function is the position of the element in the sequence that is being freed. This allows you to store objects of different types in the same custom data sequence. The `push_back()` and `insert()` functions free the passed object if the reallocation of the underlying sequence buffer fails.

When exceptions are disabled, the `push_back()`, `insert()`, and `reserve()` functions return an error code to signal the out of memory condition:

```
class data_sequence
{
public:
  enum error
  {
    error_none,
    error_no_memory
  };

  ...

public:
  error
  push_back (void*);

  error
  insert (iterator, void*);

  error
  insert (iterator, void*, iterator& result);

  error
  reserve (size_t);
};
```

The following code fragment shows how we can store and retrieve custom data in the `person` class:

```
class data
{
  ...
};

void
destroy_data (void* p, size_t)
{
  delete static_cast<data*> (p);
}

person& = ...;
person::custom_data_sequence& cd = p.custom_data ();

cd.destructor (&destroy_data);

// Store.
//
data* d = new data;
cd.push_back (d);

// Retrieve.
//
for (person::custom_data_iterator i = cd.begin (); i != cd.end (); ++i)
{
  data* d = static_cast<data*> (*i);
}
```

5 Mapping for Built-In XML Schema Types

In XML Schema, built-in types, such as `int`, `string`, etc., are defined in the XML Schema namespace. By default this namespace is mapped to C++ namespace `xml_schema` (this mapping can be altered with the `--namespace-map` option). The following table summarizes the mapping of XML Schema built-in types to C++ types in the C++/Hybrid mapping. Declarations for these types are automatically included into each generated header file.

XML Schema type	Alias in the `xml_schema` namespace	C++ type
fixed-length integral types		
`byte`	`byte`	`signed char`
`unsignedByte`	`unsigned_byte`	`unsigned char`

`short`	`short_`	`short`
`unsignedShort`	`unsigned_short`	`unsigned short`
`int`	`int_`	`int`
`unsignedInt`	`unsigned_int`	`unsigned int`
`long`	`long_`	`long` or `long long` Section 3.5, "64-bit Integer Type"
`unsignedLong`	`unsigned_long`	`unsigned long` or `unsigned long long` Section 3.5, "64-bit Integer Type"
arbitrary-length integral types		
`integer`	`integer`	`long`
`nonPositiveInteger`	`non_positive_integer`	`long`
`nonNegativeInteger`	`non_negative_integer`	`unsigned long`
`positiveInteger`	`positive_integer`	`unsigned long`
`negativeInteger`	`negative_integer`	`long`
boolean types		
`boolean`	`boolean`	`bool`
fixed-precision floating-point types		
`float`	`float_`	`float`
`double`	`double_`	`double`
arbitrary-precision floating-point types		
`decimal`	`decimal`	`double`
string types		
`string`	`string`	`std::string` or `char*` Section 3.1, "Standard Template Library"

`normalizedString`	`normalized_string`	`std::string` or `char*` Section 3.1, "Standard Template Library"
`token`	`token`	`std::string` or `char*` Section 3.1, "Standard Template Library"
`Name`	`name`	`std::string` or `char*` Section 3.1, "Standard Template Library"
`NMTOKEN`	`nmtoken`	`std::string` or `char*` Section 3.1, "Standard Template Library"
`NMTOKENS`	`nmtokens`	Section 5.2, "Mapping for `NMTOKENS` and `IDREFS`"
`NCName`	`ncname`	`std::string` or `char*` Section 3.1, "Standard Template Library"
`language`	`language`	`std::string` or `char*` Section 3.1, "Standard Template Library"
qualified name		
`QName`	`qname`	Section 5.1, "Mapping for `QName`"
ID/IDREF types		
`ID`	`id`	`std::string` or `char*` Section 3.1, "Standard Template Library"
`IDREF`	`idref`	`std::string` or `char*` Section 3.1, "Standard Template Library"
`IDREFS`	`idrefs`	Section 5.2, "Mapping for `NMTOKENS` and `IDREFS`"
URI types		

`anyURI`	`uri`	`std::string` or `char*` Section 3.1, "Standard Template Library"
binary types		
`base64Binary`	`base64_binary`	Section 5.3, "Mapping for `base64Binary` and `hexBinary`"
`hexBinary`	`hex_binary`	Section 5.3, "Mapping for `base64Binary` and `hexBinary`"
date/time types		
`date`	`date`	Section 5.5, "Mapping for `date`"
`dateTime`	`date_time`	Section 5.6, "Mapping for `dateTime`"
`duration`	`duration`	Section 5.7, "Mapping for `duration`"
`gDay`	`gday`	Section 5.8, "Mapping for `gDay`"
`gMonth`	`gmonth`	Section 5.9, "Mapping for `gMonth`"
`gMonthDay`	`gmonth_day`	Section 5.10, "Mapping for `gMonthDay`"
`gYear`	`gyear`	Section 5.11, "Mapping for `gYear`"
`gYearMonth`	`gyear_month`	Section 5.12, "Mapping for `gYearMonth`"
`time`	`time`	Section 5.13, "Mapping for `time`"

As you can see from the table above a number of built-in XML Schema types are mapped to fundamental C++ types such as `int` or `bool`. All string-based XML Schema types are mapped to either `std::string` or `char*`, depending on whether the use of STL is enabled or not. A number of built-in types, such as `QName`, the binary types, and the date/time types, do not have suitable fundamental or standard C++ types to map to. These types are implemented from scratch in the XSD/e runtime and are discussed in more detail in the subsequent sections.

In cases where the schema calls for an inheritance from a built-in type which is mapped to a fundamental C++ type, a special base type corresponding to the fundamental type and defined in the `xml_schema` namespace is used (C++ does not allow inheritance from fundamental types). For example:

```
<complexType name="measure">
  <simpleContent>
    <extension base="int">
      <attribute name="unit" type="string" use="required"/>
    </extension>
  </simpleContent>
</complexType>
```

The corresponding object model class is shown below:

```
// measure (fixed-length)
//
class measure: public xml_schema::int_base
{
public:
  measure ();
  measure (const measure&);
  measure& operator= (const measure&);

  // unit
  //
  const std::string&
  unit () const;

  std::string&
  unit ();

  void
  unit (const std::string&);

private:
  ...
};
```

The `xml_schema::int_base` class has the following interface:

```
namespace xml_schema
{
  class int_base
  {
  public:
    int_base ();

    int_base&
    operator= (int);
  public:
    int
    base_value () const;

    int&
    base_value ();

    void
    base_value (int);

    operator const int& () const;
    operator int& ();
  };
}
```

All other base types for fundamental C++ types have similar interfaces. The only exception is the base type for string types when STL is disabled:

```
namespace xml_schema
{
  class string_base
  {
  public:
    string_base ();

    string_base&
    operator= (char* x)

  public:
    const char*
    base_value () const;

    char*
    base_value ();

    void
    base_value (char* x);

    operator const char* () const;
    operator char* ();
  };
}
```

Note that the `string_base` object assumes ownership of the strings passed to the assignment operator and the `base_value()` modifier.

5.1 Mapping for `QName`

The `QName` built-in XML Schema type is mapped to the `qname` class which represents an XML qualified name. With STL enabled (Section 3.1, "Standard Template Library"), it has the following interface:

```
namespace xml_schema
{
  class qname
  {
  public:
    // The default constructor creates an uninitialized object.
    // Use modifiers to initialize it.
    //
    qname ();

    explicit
    qname (const std::string& name);
    qname (const std::string& prefix, const std::string& name);

    void
    swap (qname&);

    const std::string&
    prefix () const;

    std::string&
    prefix ();

    void
    prefix (const std::string&);

    const std::string&
    name () const;

    std::string&
    name ();

    void
    name (const std::string&);
  };

  bool
  operator== (const qname&, const qname&);

  bool
  operator!= (const qname&, const qname&);
}
```

When STL is disabled and C++ exceptions are enabled (Section 3.3, "C++ Exceptions"), the `qname` type has the following interface:

```
namespace xml_schema
{
  class qname
  {
  public:
    // The default constructor creates an uninitialized object.
    // Use modifiers to initialize it.
    //
    qname ();

    explicit
    qname (char* name);
    qname (char* prefix, char* name);

    void
    swap (qname&);

  private:
    qname (const qname&);

    qname&
    operator= (const qname&);

  public:
    char*
    prefix ();

    const char*
    prefix () const;

    void
    prefix (char*);

    void
    prefix_copy (const char*);

    char*
    prefix_detach ();

  public:
    char*
    name ();

    const char*
    name () const;

    void
    name (char*);
    void
    name_copy (const char*);

    char*
    name_detach ();
  };

  bool
  operator== (const qname&, const qname&);

  bool
  operator!= (const qname&, const qname&);
}
```

The modifier functions and constructors that have the `char*` argument assume ownership of the passed strings which should be allocated with operator `new char[]` and will be deallocated with operator `delete[]` by the `qname` object. If you detach the underlying prefix or name strings, then they should eventually be deallocated with operator `delete[]`.

Finally, if both STL and C++ exceptions are disabled, the `qname` type has the following interface:

```
namespace xml_schema
{
  class qname
  {
  public:
    enum error
    {
      error_none,
      error_no_memory
    };

    // The default constructor creates an uninitialized object.
    // Use modifiers to initialize it.
    //
    qname ();

    explicit
    qname (char* name);
    qname (char* prefix, char* name);

    void
    swap (qname&);

  private:
    qname (const qname&);

    qname&
    operator= (const qname&);

  public:
    char*
    prefix ();

    const char*
    prefix () const;

    void
    prefix (char*);

    error
    prefix_copy (const char*);

    char*
    prefix_detach ();

  public:
    char*
    name ();

    const char*
    name () const;

    void
    name (char*);

    error
    name_copy (const char*);

    char*
    name_detach ();
  };

  bool
  operator== (const qname&, const qname&);

  bool
  operator!= (const qname&, const qname&);
}
```

5.2 Mapping for `NMTOKENS` and `IDREFS`

The `NMTOKENS` and `IDREFS` built-in XML Schema types are mapped to the string sequence type which is discussed in Section 4.3, "Attributes and Elements".

5.3 Mapping for `base64Binary` and `hexBinary`

The `base64Binary` and `hexBinary` built-in XML Schema types are mapped to the `buffer` class. With C++ exceptions enabled (Section 3.3, "C++ Exceptions"), it has the following interface:

```
namespace xml_schema
{
  class buffer
  {
  public:
    class bounds {}; // Out of bounds exception.

  public:
    buffer ();

    explicit
    buffer (size_t size);
    buffer (size_t size, size_t capacity);
    buffer (const void* data, size_t size);
    buffer (const void* data, size_t size, size_t capacity);

    enum ownership_value { assume_ownership };

    // This constructor assumes ownership of the memory passed.
    //
    buffer (void* data, size_t size, size_t capacity, ownership_value);

  private:
    buffer (const buffer&);

    buffer&
    operator= (const buffer&);

  public:
    void
    attach (void* data, size_t size, size_t capacity);

    void*
    detach ();

    void
    swap (buffer&);

  public:
    size_t
    capacity () const;

    bool
    capacity (size_t);
  public:
    size_t
    size () const;

    bool
    size (size_t);

  public:
    const char*
    data () const;

    char*
    data ();

    const char*
    begin () const;

    char*
    begin ();

    const char*
    end () const;

    char*
    end ();
  };

  bool
  operator== (const buffer&, const buffer&);

  bool
  operator!= (const buffer&, const buffer&);
}
```

The last constructor and the `attach()` member function make the `buffer` instance assume the ownership of the memory block pointed to by the `data` argument and eventually release it by calling `operator delete()`. The `detach()` member function detaches and returns the underlying memory block which should eventually be released by calling `operator delete()`.

The `capacity()` and `size()` modifier functions return `true` if the underlying buffer has moved. The `bounds` exception is thrown if the constructor or `attach()` member function arguments violate the `(size <= capacity)` constraint.

If C++ exceptions are disabled, the `buffer` class has the following interface:

```
namespace xml_schema
{
  class buffer
  {
  public:
    enum error
    {
      error_none,
      error_bounds,
      error_no_memory
    };

    buffer ();

  private:
    buffer (const buffer&);

    buffer&
    operator= (const buffer&);

  public:
    error
    attach (void* data, size_t size, size_t capacity);

    void*
    detach ();

    void
    swap (buffer&);

  public:
    size_t
    capacity () const;

    error
    capacity (size_t);

    error
    capacity (size_t, bool& moved);

  public:
    size_t
    size () const;

    error
    size (size_t);

    error
    size (size_t, bool& moved);

  public:
    const char*
    data () const;

    char*
    data ();

    const char*
    begin () const;

    char*
    begin ();

    const char*
    end () const;

    char*
    end ();
  };

  bool
  operator== (const buffer&, const buffer&);

  bool
  operator!= (const buffer&, const buffer&);
}
```

5.4 Time Zone Representation

The `date`, `dateTime`, `gDay`, `gMonth`, `gMonthDay`, `gYear`, `gYearMonth`, and `time` XML Schema built-in types all include an optional time zone component. The following `time_zone` base class is used to represent this information:

```
namespace xml_schema
{
  class time_zone
  {
  public:
    time_zone ();
    time_zone (short hours, short minutes);

    bool
    zone_present () const;

    void
    zone_reset ();

    short
    zone_hours () const;

    void
    zone_hours (short);

    short
    zone_minutes () const;

    void
    zone_minutes (short);
  };

  bool
  operator== (const time_zone&, const time_zone&);

  bool
  operator!= (const time_zone&, const time_zone&);
}
```

The `zone_present()` accessor function returns `true` if the time zone is specified. The `zone_reset()` modifier function resets the time zone object to the "not specified" state. If the time zone offset is negative then both hours and minutes components should be negative.

5.5 Mapping for `date`

The `date` built-in XML Schema type is mapped to the `date` class which represents a year, a day, and a month with an optional time zone. Its interface is presented below. For more information on the base `xml_schema::time_zone` class refer to Section 5.4, "Time Zone Representation".

```
namespace xml_schema
{
  class date: public time_zone
  {
  public:
    // The default constructor creates an uninitialized object.
    // Use modifiers to initialize it.
    //
    date ();

    date (int year, unsigned short month, unsigned short day);

    date (int year, unsigned short month, unsigned short day,
          short zone_hours, short zone_minutes);

    int
    year () const;

    void
    year (int);

    unsigned short
    month () const;

    void
    month (unsigned short);

    unsigned short
    day () const;

    void
    day (unsigned short);
  };

  bool
  operator== (const date&, const date&);

  bool
  operator!= (const date&, const date&);
}
```

5.6 Mapping for `dateTime`

The `dateTime` built-in XML Schema type is mapped to the `date_time` class which represents a year, a month, a day, hours, minutes, and seconds with an optional time zone. Its interface is presented below. For more information on the base `xml_schema::time_zone` class refer to Section 5.4, "Time Zone Representation".

```
namespace xml_schema
{
  class date_time: public time_zone
  {
  public:
    // The default constructor creates an uninitialized object.
    // Use modifiers to initialize it.
    //
    date_time ();

    date_time (int year, unsigned short month, unsigned short day,
               unsigned short hours, unsigned short minutes,
               double seconds);

    date_time (int year, unsigned short month, unsigned short day,
               unsigned short hours, unsigned short minutes,
               double seconds, short zone_hours, short zone_minutes);

    int
    year () const;

    void
    year (int);
    unsigned short
    month () const;

    void
    month (unsigned short);

    unsigned short
    day () const;

    void
    day (unsigned short);

    unsigned short
    hours () const;

    void
    hours (unsigned short);

    unsigned short
    minutes () const;

    void
    minutes (unsigned short);

    double
    seconds () const;

    void
    seconds (double);
  };

  bool
  operator== (const date_time&, const date_time&);

  bool
  operator!= (const date_time&, const date_time&);
}
```

5.7 Mapping for `duration`

The `duration` built-in XML Schema type is mapped to the `duration` class which represents a potentially negative duration in the form of years, months, days, hours, minutes, and seconds. Its interface is presented below.

```
namespace xml_schema
{
  class duration
  {
  public:
    // The default constructor creates an uninitialized object.
    // Use modifiers to initialize it.
    //
    duration ();

    duration (bool negative,
              unsigned int years, unsigned int months, unsigned int days,
              unsigned int hours, unsigned int minutes, double seconds);

    bool
    negative () const;

    void
    negative (bool);

    unsigned int
    years () const;

    void
    years (unsigned int);

    unsigned int
    months () const;

    void
    months (unsigned int);

    unsigned int
    days () const;

    void
    days (unsigned int);

    unsigned int
    hours () const;

    void
    hours (unsigned int);

    unsigned int
    minutes () const;

    void
    minutes (unsigned int);

    double
    seconds () const;

    void
    seconds (double);
  };
  bool
  operator== (const duration&, const duration&);

  bool
  operator!= (const duration&, const duration&);
}
```

5.8 Mapping for `gDay`

The `gDay` built-in XML Schema type is mapped to the `gday` class which represents a day of the month with an optional time zone. Its interface is presented below. For more information on the base `xml_schema::time_zone` class refer to Section 5.4, "Time Zone Representation".

```
namespace xml_schema
{
  class gday: public time_zone
  {
  public:
    // The default constructor creates an uninitialized object.
    // Use modifiers to initialize it.
    //
    gday ();

    explicit
    gday (unsigned short day);

    gday (unsigned short day, short zone_hours, short zone_minutes);

    unsigned short
    day () const;

    void
    day (unsigned short);
  };

  bool
  operator== (const gday&, const gday&);

  bool
  operator!= (const gday&, const gday&);
}
```

5.9 Mapping for `gMonth`

The `gMonth` built-in XML Schema type is mapped to the `gmonth` class which represents a month of the year with an optional time zone. Its interface is presented below. For more information on the base `xml_schema::time_zone` class refer to Section 5.4, "Time Zone Representation".

```
namespace xml_schema
{
  class gmonth: public time_zone
  {
  public:
    // The default constructor creates an uninitialized object.
    // Use modifiers to initialize it.
    //
    gmonth ();

    explicit
    gmonth (unsigned short month);

    gmonth (unsigned short month,
            short zone_hours, short zone_minutes);

    unsigned short
    month () const;

    void
    month (unsigned short);
  };

  bool
  operator== (const gmonth&, const gmonth&);

  bool
  operator!= (const gmonth&, const gmonth&);
}
```

5.10 Mapping for `gMonthDay`

The `gMonthDay` built-in XML Schema type is mapped to the `gmonth_day` class which represents a day and a month of the year with an optional time zone. Its interface is presented below. For more information on the base `xml_schema::time_zone` class refer to Section 5.4, "Time Zone Representation".

```
namespace xml_schema
{
  class gmonth_day: public time_zone
  {
  public:
    // The default constructor creates an uninitialized object.
    // Use modifiers to initialize it.
    //
    gmonth_day ();

    gmonth_day (unsigned short month, unsigned short day);

    gmonth_day (unsigned short month, unsigned short day,
                short zone_hours, short zone_minutes);

    unsigned short
    month () const;

    void
    month (unsigned short);

    unsigned short
    day () const;

    void
    day (unsigned short);
  };

  bool
  operator== (const gmonth_day&, const gmonth_day&);

  bool
  operator!= (const gmonth_day&, const gmonth_day&);
}
```

5.11 Mapping for `gYear`

The `gYear` built-in XML Schema type is mapped to the `gyear` class which represents a year with an optional time zone. Its interface is presented below. For more information on the base `xml_schema::time_zone` class refer to Section 5.4, "Time Zone Representation".

```
namespace xml_schema
{
  class gyear: public time_zone
  {
  public:
    // The default constructor creates an uninitialized object.
    // Use modifiers to initialize it.
    //
    gyear ();

    explicit
    gyear (int year);

    gyear (int year, short zone_hours, short zone_minutes);

    int
    year () const;

    void
    year (int);
  };
  bool
  operator== (const gyear&, const gyear&);

  bool
  operator!= (const gyear&, const gyear&);
}
```

5.12 Mapping for `gYearMonth`

The `gYearMonth` built-in XML Schema type is mapped to the `gyear_month` class which represents a year and a month with an optional time zone. Its interface is presented below. For more information on the base `xml_schema::time_zone` class refer to Section 5.4, "Time Zone Representation".

```
namespace xml_schema
{
  class gyear_month: public time_zone
  {
  public:
    // The default constructor creates an uninitialized object.
    // Use modifiers to initialize it.
    //
    gyear_month ();

    gyear_month (int year, unsigned short month);

    gyear_month (int year, unsigned short month,
                 short zone_hours, short zone_minutes);

    int
    year () const;

    void
    year (int);

    unsigned short
    month () const;

    void
    month (unsigned short);
  };

  bool
  operator== (const gyear_month&, const gyear_month&);

  bool
  operator!= (const gyear_month&, const gyear_month&);
}
```

5.13 Mapping for `time`

The `time` built-in XML Schema type is mapped to the `time` class which represents hours, minutes, and seconds with an optional time zone. Its interface is presented below. For more information on the base `xml_schema::time_zone` class refer to Section 5.4, "Time Zone Representation".

```
namespace xml_schema
{
  class time: public time_zone
  {
  public:
    // The default constructor creates an uninitialized object.
    // Use modifiers to initialize it.
    //
    time ();

    time (unsigned short hours, unsigned short minutes, double seconds);

    time (unsigned short hours, unsigned short minutes, double seconds,
          short zone_hours, short zone_minutes);

    unsigned short
    hours () const;

    void
    hours (unsigned short);

    unsigned short
    minutes () const;

    void
    minutes (unsigned short);

    double
    seconds () const;

    void
    seconds (double);
  };

  bool
  operator== (const time&, const time&);

  bool
  operator!= (const time&, const time&);
}
```

6 Parsing and Serialization

As was mentioned in the introduction, the C++/Hybrid mapping uses the C++/Parser and C++/Serializer mappings for XML parsing and serialization. If your parsing and serialization requirements are fairly basic, for example, parsing from and serializing to a file or a memory buffer, then you don’t need to concern yourself with these two underlying mappings. On the other hand, the C++/Parser and C++/Serializer mappings provide well-defined APIs which allow a great amount of flexibility that may be useful in certain situations. In such cases, you may need to get an understanding of how the C++/Parser and C++/Serializer mappings work. See the Embedded C++/Parser Mapping Getting Started Guide and the Embedded C++/Serializer Mapping Getting Started Guide for more detailed information on these mappings.

For each type defined in XML Schema, the C++/Parser and C++/Serializer mappings generate a parser skeleton class and serializer skeleton class, respectively. These classes manage parsing/serialization state, convert data between text and C++ types, and perform XML Schema validation, if enabled. Parser skeletons deliver the parsed data and serializer skeletons request the data to be serialized with callbacks. These callbacks are implemented by parser and serializer implementation classes that are derived from the skeletons. If the application uses the C++/Parser and C++/Serializer mappings directly, these implementation classes are normally written by the application developer to perform some application-specific actions. In case of the C++/Hybrid mapping, these implementations are automatically generated by the XSD/e compiler to parse XML to object models and to serialize object models to XML. To request the generation of parser skeletons and implementations, you need to specify the `--generate-parser` XSD/e command line option. Similarly, to generate serializer skeletons and implementations, you will need to use the `--generate-serializer` option.

Before an XML document can be parsed or serialized, the individual parser and serializer implementations need to be instantiated and connected to each other. Again, if the application uses the C++/Parser and C++/Serializer mappings directly, this is done by the application developer. While you can also do this with the generated C++/Hybrid parser and serializer implementations, it is easier to request the generation of parser and serializer aggregate classes with the `--generate-aggregate` options. Aggregate classes instantiate and connect all the necessary individual parser and serializer implementations for a particular root element or type. Consider again the `hello.xsd` schema from Chapter 2, "Hello World Example":

```
<?xml version="1.0"?>
<xs:schema xmlns:xs="http://www.w3.org/2001/XMLSchema">

  <xs:complexType name="hello">
    <xs:sequence>
      <xs:element name="greeting" type="xs:string"/>
      <xs:element name="name" type="xs:string" maxOccurs="unbounded"/>
    </xs:sequence>
  </xs:complexType>
  <xs:element name="hello" type="hello"/>

</xs:schema>
```

If we compile this schema with the `--generate-parser`, `--generate-serializer`, and `--generate-aggregate` options, we will have two aggregate classes, `hello_paggr` and `hello_saggr`, generated for the root `hello` element. The interface of the `hello_paggr` class is presented below:

```
class hello_paggr
{
public:
  hello_paggr ();

  void
  pre ();

  hello*
  post ();

  hello_pimpl&
  root_parser ();

  static const char*
  root_name ();

  static const char*
  root_namespace ();
};
```

The `pre()` and `post()` functions call the corresponding callbacks on the root parser implementation. The `root_parser()` function returns the root parser implementation. The `root_name()` and `root_namespace()` functions return the root element name and namespace, respectively.

As was shown in Chapter 2, "Hello World Example", we can use this parser aggregate to create the document parser (supplied by the C++/Parser mapping) and perform the parsing:

```
hello_paggr hello_p;
xml_schema::document_pimpl doc_p (hello_p.root_parser (),
                                  hello_p.root_name ());
hello_p.pre ();
doc_p.parse ("hello.xml");
hello* h = hello_p.post ();
```

For more information on the `document_pimpl` class, including the other variants of the `parse()` function as well as error handling during parsing, see Chapter 7, "Document Parser and Error Handling" in the Embedded C++/Parser Mapping Getting Started Guide.

The interface of the `hello_saggr` serializer aggregate mirrors that of `hello_paggr` and is presented below:

```
class hello_saggr
{
public:
  hello_saggr ();

  void
  pre (const hello&);

  void
  post ();

  hello_simpl&
  root_serializer ();

  static const char*
  root_name ();

  static const char*
  root_namespace ();
};
```

The `pre()` and `post()` functions call the corresponding callbacks on the root serializer implementation. The `root_serializer()` function returns the root serializer implementation. The `root_name()` and `root_namespace()` functions return the root element name and namespace, respectively.

As was shown in Chapter 2, "Hello World Example", we can use this serializer aggregate to create the document serializer (supplied by the C++/Serializer mapping) and perform the serialization:

```
hello_saggr hello_s;
xml_schema::document_simpl doc_s (hello_s.root_serializer (),
                                  hello_s.root_name ());
hello_s.pre (*h);
doc_s.serialize (std::cout);
hello_s.post ();
```

For more information on the `document_simpl` class, including the other variants of the `serialize()` function as well as error handling during serialization, see Chapter 8, "Document Serializer and Error Handling" in the Embedded C++/Serializer Mapping Getting Started Guide.

6.1 Customizing Parsers and Serializers

The C++/Hybrid mapping allows you to customize the generated parser and serializer implementations. This mechanism can be used, for example, to implement filtering, partially event-driven XML processing, as well as parsing of content matched by XML Schema wildcards. Filtering allows only parts of the XML document to be parsed into the object model or only parts of the object model to be serialized to XML. With partially event-driven parsing and serialization, we can process parts of the document as they become available as well as handle documents that are too large to fit into memory. This section expects you to have an understanding of the C++/Parser and C++/Serializer programming models.

To request customization of a parser or serializer implementation, you will need to specify the `--custom-parser` or `--custom-serializer` option, respectively. The argument format for these two options is `type[=base[/include]]`. The `type` component is the XML Schema type name being customized. Optional `base` is a C++ name that should be given to the generated version. It is normally used as a base for the custom implementation. Optional `include` is the header file that defines the custom implementation. It is `#include`’ed into the generated code immediately after (if `base` is specified) or instead of the generated version. The following examples show how we can use these options:

```
--custom-parser foo
--custom-parser foo=foo_base_pimpl
--custom-parser foo=foo_base_pimpl/foo/foo-custom.hxx
--custom-parser foo=/foo/foo-custom.hxx
```

The first version instructs the XSD/e compiler not to generate the parser implementation for the `foo` XML Schema type. The second version instructs the compiler to generate the parser implementation for type `foo` but call it `foo_base_pimpl`. The third version is similar to the second except that the compiler generates the `#include` directive with the `foo/foo-custom.hxx` file (which presumably defines `foo_pimpl`) right after the `foo_base_pimpl` class. The last version instructs the XSD/e compiler to include `foo/foo-custom.hxx` instead of generating the parser implementation for `foo`. If you omit the last component, then you can include the custom parser/serializer definitions using one of the prologue or epilogue XSD/e compiler options. See the XSD/e Compiler Command Line Manual for details.

Once you specify the `--custom-parser` or `--custom-serializer` option, you will need to provide the custom implementation. You have a choice of either basing it on the generated version and overriding some callbacks or implementing it from scratch.

In the remainder of this section we will examine how to customize the `people` parser and serializer implementations from the example presented in Chapter 4, "Working with Object Models". Our custom parser implementation will filter the records being parsed based on a person’s age. Similarly, the serializer will only serialize records of a specific gender. The code presented below is taken from the `filter` example in the XSD/e distribution. Other examples related to parser/serializer customization are `wildcard` and `streaming`.

First, we compile the `people.xsd` schema and instruct the XSD/e compiler to customize the parser and serializer implementations for the `people` XML Schema type:

```
$ xsde cxx-hybrid --generate-parser --generate-serializer \
--custom-parser people=people_base_pimpl/people-custom-pimpl.hxx \
--custom-serializer people=people_base_simpl/people-custom-simpl.hxx \
--generate-aggregate people.xsd
```

The custom `people_pimpl` parser implementation is based on the generated version and is saved to `people-custom-pimpl.hxx`:

```
class people_pimpl: public people_base_pimpl
{
public:
  void
  age_filter (unsigned short min, unsigned short max)
  {
    min_age_ = min;
    max_age_ = max;
  }

  virtual void
  person (const ::person& p)
  {
    // Check if the age constraints are met.
    //
    unsigned short age = p.age ();

    if (age >= min_age_ && age <= max_age_)
      people_base_pimpl::person (p);
  }

private:
  unsigned short min_age_;
  unsigned short max_age_;
};
```

Here we override the `person()` callback and, if the filter conditions are satisfied, call the original version which adds the person record to the object model. Note that if the `person` object model class were variable-length, then the instance would be dynamically allocated and passed as a pointer. In this situation, if we don’t use the object, we need to delete it, for example:

```
virtual void
person (const ::person* p)
{
  unsigned short age = p->age ();

  if (age >= min_age_ && age <= max_age_)
    people_base_pimpl::person (p);
  else
    delete p;
}
```

The custom `people_simpl` parser implementation is also based on the generated version and is saved to `people-custom-simpl.hxx`:

```
class people_simpl: public people_base_simpl
{
public:
  void
  gender_filter (gender g)
  {
    gender_ = g;
  }

  virtual bool
  person_next ()
  {
    // See if we have any more person records with the gender we
    // are interested in.
    //
    people::person_const_iterator& i = people_base_simpl_state_.person_;
    people::person_const_iterator& e = people_base_simpl_state_.person_end_;

    for (; i != e; ++i)
    {
      if (i->gender () == gender_)
        break;
    }

    return i != e;
  }

private:
  gender gender_;
};
```

Here we override the `person_next()` callback where we locate the next record that satisfies the filter conditions. Note that we use the serialization state provided by the generated `people_base_simpl` implementation.

The following code fragment shows a test driver that uses the above implementations to filter the data during parsing and serialization:

```
#include <memory>
#include <iostream>

#include "people.hxx"

#include "people-pimpl.hxx"
#include "people-simpl.hxx"

using namespace std;

int
main (int argc, char* argv[])
{
  // Parse.
  //
  people_paggr people_p;
  people_pimpl& root_p = people_p.root_parser ();

  // Initialize the filter.
  //
  root_p.age_filter (1, 30);

  xml_schema::document_pimpl doc_p (root_p, people_p.root_name ());

  people_p.pre ();
  doc_p.parse (argv[1]);
  auto_ptr<people> ppl (people_p.post ());

  // Print what we’ve got.
  //
  people::person_sequence& ps = ppl->person ();

  for (people::person_iterator i = ps.begin (); i != ps.end (); ++i)
  {
    cerr << "first:  " << i->first_name () << endl
         << "last:   " << i->last_name () << endl
         << "gender: " << i->gender () << endl
         << "age:    " << i->age () << endl
         << endl;
  }

  // Serialize.
  //
  people_saggr people_s;
  people_simpl& root_s = people_s.root_serializer ();

  // Initialize the filter.
  //
  gender g;
  g.assign ("female");
  root_s.gender_filter (g);

  xml_schema::document_simpl doc_s (root_s, people_s.root_name ());

  people_s.pre (*ppl);
  doc_s.serialize (cout);
  people_s.post ();
}
```

If we run this test driver on the following XML document:

```
<?xml version="1.0"?>
<people>

  <person>
    <first-name>John</first-name>
    <last-name>Doe</last-name>
    <gender>male</gender>
    <age>32</age>
  </person>

  <person>
    <first-name>Jane</first-name>
    <last-name>Doe</last-name>
    <gender>female</gender>
    <age>28</age>
  </person>

  <person>
    <first-name>Joe</first-name>
    <last-name>Dirt</last-name>
    <gender>male</gender>
    <age>25</age>
  </person>

</people>
```

We will get the following output:

```
first:  Jane
last:   Doe
gender: female
age:    28

first:  Joe
last:   Dirt
gender: male
age:    25
```

```
<people>
  <person>
    <first-name>Jane</first-name>
    <last-name>Doe</last-name>
    <gender>female</gender>
    <age>28</age>
  </person>
</people>
```