SOMobjects Base Toolkit

Users Guide

An introductory guide to the base capabilities of the System Object Model and its basic frameworks

Version 2.0
January 1994

Note: Before using this information and the product it supports, be sure to read the trademark information under "Notices" on page ix.

Second Edition (January 1994)

SOMobjects Base Toolkit Users Guide

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Chapter 6. Distributed SOM (DSOM)

About This Book

This book accompanies the **SOMobjects Base Toolkit**, which consists of the base (or core) capabilities in the **System Object Model** (**SOM**) of the **SOMobjects Developer Toolkit.** The base system is a rich subset of the full-capability SOMobjects Developer Toolkit. Because the current manual is a subset of chapters from the full *SOMobjects Developer Toolkit Users Guide*, references herein to the "SOMobjects Developer Toolkit" should be interpreted as capabilities of the SOMobjects Base Toolkit.

This manual explains how programmers using C, C++, and other languages can

- Implement class libraries that exploit the SOM library-packaging technology,
- Develop client programs that use class libraries that were built using SOM, and
- Develop applications that use the *frameworks* supplied with this core version of the SOMobjects Toolkit, class libraries that facilitate development of object-oriented applications.

In addition to this book, refer to the *SOMobjects Base Toolkit Programmers Reference Manual* during application development for specific information about the classes, methods, functions, and macros of the SOMobjects Toolkit. Also, the *SOMobjects Base Toolkit Quick Reference Guide* shows the syntax of each method or function, along with a one-sentence description of its purpose, and gives syntax for the SOM Compiler commands and option flags.

For purchasers of the full-capability SOMobjects system, the *SOMobjects Developer Toolkit: Emitter Framework Guide and Reference* contains documentation of the Emitter Framework of the SOMobjects Developer Toolkit. In addition, the *SOMobjects Developer Toolkit: Collection Classes Reference Manual* describes the collection classes and methods provided with the SOMobjects Developer Toolkit.

How This Book Is Organized

This book contains nine chapters, three appendices, a glossary, and an index.

- The first part (chapters 1 and 2) introduces the reader to the SOMobjects Toolkit, gives an overview of the major elements of SOM, and provides a Tutorial containing several evolutionary examples.
- The second part (chapter 3) describes how to develop client programs in C, C++, or other languages to use classes that were implemented using SOM, including how to create instances of a class and call methods on them.
- The third part (chapters 4 and 5) describes the SOM run-time environment, gives the syntax of the SOM Interface Definition Language, provides directions for running the SOM Compiler, and contains advanced information about SOM's object model and how to customize SOM for particular applications.
- The fourth part (chapters 6 through 9) contains information about the frameworks composing the SOMobjects Toolkit: Distributed SOM (DSOM), the Interface Repository Framework, and the Event Management Framework. This part also describes the utility metaclasses provided with the SOMobjects Toolkit.
- The appendices describe customer support-procedures and error codes, and provide the grammar for SOM IDL. The final appendix describes how to subclass a "Sockets" class that facilitates inter-process communications required by the DSOM and Event Management Frameworks.
- The Glossary provides brief definitions of terminology related to SOM and the SOMobjects Toolkit. Finally, an extensive Index enables the reader to locate specific information quickly.

Who Should Read This Book

This book is for the professional programmer using C, C++, or another language who wishes to

- Use SOM to build object–oriented class libraries, or
- Write application programs using class libraries that others have implemented using SOM,

even if the programming language does not directly support object–oriented programming.

The discussions in this book are expressed in the commonly used terminology of object-oriented programming. A number of important terms are everyday English words that take on specialized meanings. These terms appear in the Glossary at the back of this book. You may find it worth consulting the Glossary if the unusual significance attached to an otherwise ordinary word puzzles you.

This book assumes that you are an experienced programmer and that you have a general familiarity with the basic notions of object-oriented programming. Practical experience using an object-oriented programming language is helpful, but not essential.

If you would like a good introduction to object-oriented programming or a general survey of the many aspects of the topic, you might enjoy reading one of the following books:

- Booch, G, *Object-Oriented Design with Applications*, Benjamin/Cummings 1991, ISBN 0-8053-0091-0.
- Budd, T, *An Introduction to Object-Oriented Programming*, Addison-Wesley 1991, ISBN 0-201-54709-0.
- Cox, B, and Novobilski, A, *Object-Oriented Programming, An Evolutionary Approach* 2nd Edition, Addison-Wesley 1991, ISBN 0-201-54834-8.

Notices

The following terms are trademarks of the International Business Machines Corporation in the United States and/or other countries:

AIX
Operating System/2
OS/2
OS/2 Workplace Shell
RISC System 6000
SOMobjects
System Object Model

For convenience, the acronym "SOM" is used in this publication to reference the technology of the System Object Model, and the term "SOM Compiler" is used to reference the compiler of the System Object Model.

Each of the following terms used in this publication is a trademark of another company:

Intel	Intel Corporation
IPX	Novell Corporation
Lotus 1-2-3	Lotus Development Corporation
Microsoft EXCEL	Microsoft Corporation
Microsoft Windows	Microsoft Corporation
NetWare	Novell Corporation
Objective-C	The Stepstone Corporation
Smalltalk	Digitalk Inc.

The term "ANSI C" used throughout this publication refers to American National Standard X3.159–1989.

The term "CORBA" used throughout this publication refers to the Common Object Request Broker Architecture standards promulgated by the Object Management Group, Inc.

Chapter 1. Introduction to the SOMobjects Toolkit

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Chapter 1. Introduction to the SOMobjects Toolkit

1.1 Background

Object-oriented programming (or **OOP**) is an important new programming technology that offers expanded opportunities for software reuse and extensibility. Object-oriented programming shifts the emphasis of software development away from functional decomposition and toward the recognition of units (called *objects*) that encapsulate both code and data. As a result, programs become easier to maintain and enhance. Object-oriented programs are typically more impervious to the “ripple effects” of subsequent design changes than their non-object-oriented counterparts. This, in turn, leads to improvements in programmer productivity.

Despite its promise, penetration of object-oriented technology to major commercial software products has progressed slowly because of certain obstacles. This is particularly true of products that offer only a binary programming interface to their internal object classes *(i.e.,* products that do not allow access to source code).

The first obstacle that developers must confront is the choice of an object-oriented programming language.

So-called “pure” object-oriented languages (such as Smalltalk) presume a complete run-time environment (sometimes known as a virtual machine), because their semantics represent a major departure from traditional, procedure-oriented system architectures. So long as the developer works within the supplied environment, everything works smoothly and consistently. When the need arises to interact with foreign environments, however (for example, to make an external procedure call), the pure-object paradigm ends, and objects must be reduced to data structures for external manipulation. Unfortunately, data structures do not retain the advantages that objects offer with regard to encapsulation and code reuse.

“Hybrid” languages such as C++, on the other hand, require less run-time support, but sometimes result in tight bindings between programs that implement objects (called “class libraries”) and their clients (the programs that use them). That is, implementation detail is often unavoidably compiled into the client programs. Tight binding between class libraries and their clients means that client programs often must be recompiled whenever simple changes are made in the library. Furthermore, no binary standard exists for C++ objects, so the C++ class libraries produced by one C++ compiler cannot (in general) be used from C++ programs built with a different C++ compiler.

The second obstacle developers of object-oriented software must confront is that, because different object-oriented languages and toolkits embrace incompatible models of what objects are and how they work, software developed using a particular language or toolkit is naturally limited in scope. Classes implemented in one language cannot be readily used from another. A C++ programmer, for example, cannot easily use classes developed in Smalltalk, nor can a Smalltalk programmer make effective use of C++ classes. Object-oriented language and toolkit boundaries become, in effect, barriers to interoperability.

Ironically, no such barrier exists for ordinary procedure libraries. Software developers routinely construct procedure libraries that can be shared across a variety of languages, by adhering to standard linkage conventions. Object-oriented class libraries are inherently different in that no binary standards or conventions exist to derive a new class from an existing one, or even to invoke a method in a standard way. Procedure libraries also enjoy the benefit that their implementations can be freely changed without requiring client programs to be recompiled, unlike the situation for C++ class libraries.

For developers who need to provide binary class libraries, these are serious obstacles. In an era of open systems and heterogeneous networking, a single-language solution is frequently not broad enough. Certainly, mandating a specific compiler from a specific vendor in order to use a class library might be grounds not to include the class library with an operating system or other general-purpose product.

The **System Object Model (SOM)** is IBM's solution to these problems.

1.2 Introducing SOM and the SOMobjects Toolkit

The **System Object Model (SOM)** is a new object-oriented programming technology for building, packaging, and manipulating binary *class libraries*.

- With SOM, class implementors describe the *interface* for a class of objects (names of the methods it supports, the return types, parameter types, and so forth) in a standard language called the **Interface Definition Language**, or **IDL**.
- They then *implement* methods in their preferred programming language (which may be either an object-oriented programming language or a procedural language such as C).

This means that programmers can begin using SOM quickly, and also extends the advantages of OOP to programmers who use non-object-oriented programming languages.

A principal benefit of using SOM is that SOM accommodates changes in implementation details and even in certain facets of a class's interface, without breaking the binary interface to a class library and without requiring recompilation of client programs. As a rule of thumb, if changes to a SOM class do not require source-code changes in client programs, then those client programs will not need to be recompiled. This is not true of many object-oriented languages, and it is one of the chief benefits of using SOM. For instance, SOM classes can undergo structural changes such as the following, yet retain full backward, binary compatibility:

- Adding new methods,
- Changing the size of an object by adding or deleting instance variables,
- Inserting new parent (base) classes above a class in the inheritance hierarchy, and
- Relocating methods upward in the class hierarchy.

In short, implementors can make the typical kinds of changes to an implementation and its interfaces that evolving software systems experience over time.

Unlike the object models found in formal object-oriented programming languages, SOM is language-neutral. It preserves the key OOP characteristics of encapsulation, inheritance, and polymorphism, without requiring that the user of a SOM class and the implementor of a SOM class use the same programming language. SOM is said to be *language-neutral* for four reasons:

1. All SOM interactions consist of standard procedure calls. On systems that have a standard linkage convention for system calls, SOM interactions conform to those conventions. Thus, most programming languages that can make external procedure calls can use SOM.
2. The form of the SOM Application Programming Interface, or API (the way that programmers invoke methods, create objects, and so on) can vary widely from language to language, as a benefit of the SOM bindings. *Bindings* are a set of macros and procedure calls that make implementing and using SOM classes more convenient by tailoring the interface to a particular programming language.
3. SOM supports several mechanisms for method resolution that can be readily mapped into the semantics of a wide range of object-oriented programming languages. Thus, SOM class libraries can be shared across object-oriented languages that have differing object models. A SOM object can potentially be accessed with three different forms of method resolution:
   - Offset resolution: roughly equivalent to the C++ "virtual function" concept. Offset resolution implies a static scheme for typing objects, with polymorphism based strictly on class derivation. It offers the best performance characteristics for SOM method resolution. Methods accessible through offset resolution are called *static* methods, because they are considered a fixed aspect of an object's interface.

- Name-lookup resolution: similar to that employed by Objective-C and Smalltalk. Name resolution supports untyped (sometimes called "dynamically" typed) access to objects, with polymorphism based on the actual protocols that objects honor. Name resolution offers the opportunity to write code to manipulate objects with little or no awareness of the type or shape of the object when the code is compiled.
- Dispatch-function resolution: a unique feature of SOM that permits method resolution based on arbitrary rules known only in the domain of the receiving object. Languages that require special entry or exit sequences or local objects that represent distributed object domains are good candidates for using dispatch-function resolution. This technique offers the highest degree of encapsulation for the implementation of an object, with some cost in performance.

4. SOM conforms fully with the Object Management Group's (OMG) Common Object Request Broker Architecture (CORBA) standards.† In particular,
   - Interfaces to SOM classes are described in CORBA's Interface Definition Language, IDL, and the entire SOMobjects Toolkit supports all CORBA-defined data types.
   - The SOM bindings for the C language are compatible with the C bindings prescribed by CORBA.
   - All information about the interface to a SOM class is available at run time through a CORBA-defined "Interface Repository."

SOM is not intended to replace existing object-oriented languages. Rather, it is intended to complement them so that application programs written in different programming languages can share common SOM class libraries. For example, SOM can be used with C++ to

- Provide upwardly compatible class libraries, so that when a new version of a SOM class is released, client code needn't be recompiled, so long as no changes to the client's source code are required.
- Allow other language users (and other C++ compiler users) to use SOM classes implemented in C++.
- Allow C++ programs to use SOM classes implemented using other languages.
- Allow other language users to implement SOM classes derived from SOM classes implemented in C++.
- Allow C++ programmers to implement SOM classes derived from SOM classes implemented using other languages.
- Allow encapsulation (implementation hiding) so that SOM class libraries can be shared without exposing private instance variables and methods.
- Allow dynamic (run-time) method resolution in addition to static (compile-time) method resolution (on SOM objects).
- Allow information about classes to be obtained and updated at run time. (C++ classes are compile-time structures that have no properties at run time.)

The SOM Compiler

The **SOMobjects Toolkit** contains a tool, called the **SOM Compiler**, that helps implementors build classes in which *interface* and *implementation* are decoupled. The SOM Compiler reads the IDL definition of a class interface and generates:

- an implementation skeleton for the class,
- bindings for implementors, and
- bindings for client programs.

†OMG is an industry consortium founded to advance the use of object technology in distributed, heterogeneous environments.

Bindings are language-specific macros and procedures that make implementing and using SOM classes more convenient. These bindings offer a convenient interface to SOM that is tailored to a particular programming language. For instance, C programmers can invoke methods in the same way they make ordinary procedure calls. The C++ bindings "wrap" SOM objects as C++ objects, so that C++ programmers can invoke methods on SOM objects in the same way they invoke methods on C++ objects. In addition, SOM objects receive full C++ typechecking, just as C++ objects do. Currently, the SOM Compiler can generate both C and C++ language bindings for a class. The C and C++ bindings will work with a variety of commercial products available from IBM and others. Vendors of other programming languages may also offer SOM bindings. Check with your language vendor about possible SOM support.

The SOM run-time library

In addition to the SOM Compiler, SOM includes a **run-time library**. This library provides, among other things, a set of classes, methods, and procedures used to create objects and invoke methods on them. The library allows any programming language to use SOM classes (classes developed using SOM) if that language can:

- Call external procedures,
- Store a pointer to a procedure and subsequently invoke that procedure, and
- Map IDL types onto the programming language's native types.

Thus, the user of a SOM class and the implementor of a SOM class needn't use the same programming language, and neither is required to use an object-oriented language. The independence of client language and implementation language also extends to subclassing: a SOM class can be derived from other SOM classes, and the subclass may or may not be implemented in the same language as the parent class(es). Moreover, SOM's run-time environment allows applications to access information about classes dynamically (at run time).

Frameworks provided in the SOMobjects Toolkit

In addition to SOM itself (the SOM Compiler and the SOM run-time library), the SOMobjects Developer Toolkit provides a set of *frameworks* (class libraries) that can be used in developing object-oriented applications. These include Distributed SOM, the Interface Repository Framework, the Persistence Framework, the Replication Framework, and the Emitter Framework, described below.

Note: **SOMobjects Base Toolkit**, the core version of SOMobjects shipped with this manual, contains *only* the Distributed SOM and Interface Repository frameworks. The complete SOMobjects Developer Toolkit can be ordered from IBM by calling 1–800–342–6672 in the U.S. or 1–800–465–7999 in Canada. Part numbers are 96F8647 for the OS/2 version or 96F8648 for the AIX version (both of which include all publications), and 96F8649 for a separate publications package.

Distributed SOM

Distributed SOM (or **DSOM**) allows application programs to access SOM objects across address spaces. That is, application programs can access objects in other processes, even on a different machine. DSOM provides this transparent access to remote objects through its Object Request Broker (ORB): the location and implementation of the object are hidden from the client, and the client accesses the object as if were local. DSOM in the core-capability SOMobjects Base Toolkit supports distribution of objects among processes within a single workstation. The full-capability version of DSOM also supports distribution across a local area network consisting of AIX systems, OS/2 systems, or some mix of these systems. Future releases may support larger, enterprise-wide networks.

Interface Repository Framework

The **Interface Repository** is a database, optionally created and maintained by the SOM Compiler, that holds all the information contained in the IDL description of a class of objects. The **Interface Repository Framework** consists of the 11 classes defined in the CORBA standard for accessing the Interface Repository. Thus, the Interface Repository Framework provides run-time access to all information contained in the IDL description of a class of objects. Type information is available as **TypeCode**s — a CORBA-defined way of encoding the complete description of any data type that can be constructed in IDL.

Persistence Framework

The **Persistence Framework** is a collection of SOM classes that provide methods for saving objects (either in a file or in a more specialized repository) and later restoring them. This means that the state of an object can be preserved beyond the termination of the process that creates it. This facility is useful for constructing object-oriented databases, spreadsheets, and so forth. The Persistence Framework includes the following features:

- Objects can be stored singly or in groups.
- Objects can be stored in default formats or in specially designed formats.
- Objects of arbitrary complexity can be saved and restored.

Replication Framework

The **Replication Framework** is a collection of SOM classes that allows a replica (copy) of an object to exist in multiple address spaces, while maintaining a single-copy image. In other words, an object can be replicated in several different processes, while logically it behaves as a single copy. Updates to any copy are propagated immediately to all other copies. The Replication Framework handles locking, synchronization, and update propagation, and guarantees mutual consistency among the replicas. The Replication Framework includes these important features:

- Good response times for both readers and writers,
- Fault-tolerance against node failures and message loss,
- Simple coding rules (that can be automated) for building replicated objects,
- Graceful degradation under wide-area networks, and
- Minimal overhead when replication is not activated.

Emitter Framework

Finally, the **Emitter Framework** is a collection of SOM classes that allows programmers to write their own emitters. *Emitter* is a general term used to describe a back-end output component of the SOM Compiler. Each emitter takes as input information about an interface, generated by the SOM Compiler as it processes an IDL specification, and produces output organized in a different format. SOM provides a set of emitters that generate the binding files for C and C++ programming (header files and implementation templates). In addition, users may wish to write their own special-purpose emitters. For example, an implementor could write an emitter to produce documentation files or binding files for programming languages other than C/C++. The Emitter Framework is separately documented in the *SOMobjects Developer Toolkit: Emitter Framework Guide and Reference.*

1.3 What's New in the SOMobjects Developer Toolkit

The SOMobjects Toolkit is a major step up from SOM Version 1.0 in terms of functionality, usability, standardization, performance, and documentation. In particular, the SOMobjects Developer Toolkit Version 2.0 offers the following additions over SOM Version 1.0:

- C++ bindings
- Multiple platforms (OS/2 and AIX)
- Multiple inheritance (when using IDL)
- Derived metaclasses
- CORBA compliance (including IDL)
- SOM Compiler that handles both IDL and OIDL interface descriptions
- Full binary compatibility with SOM 1.0
- Improved method resolution
- Improved memory management
- Improved error checking
- Faster emitters
- Smaller and faster binaries for class libraries
- Header files that automatically prevent name collisions
- Smaller implementation header files
- Ability to package multiple classes in a single file, as an IDL module
- Ability to define (in IDL) methods that return structures
- Ability to use a C/C++ preprocessor within .idl files
- Improved incremental update of implementation files
- With IDL, full type checking and full name scoping
- Class shadowing (described in the *Emitter Framework Guide and Reference*)
- DSOM, which enables distribution of SOM objects across processes (see Chapter 6)
- Automatic generation and revision of an Interface Repository (see Chapter 7)
- Persistence Framework, which simplifies creating persistent objects (see Chapter 8)
- Replication Framework, which enables construction of replicated objects (see Chapter 9)
- Utility metaclasses (see Chapter 10)
- Collection classes (see Chapter 11)
- An Event Manager (see Chapter 12)
- Tools for automatically converting .csc files to .idl files (see Appendix B)
- Emitter Framework, which allows developers to write their own emitters (documented in the *Emitter Framework Guide and Reference*)

1.4 Overview of this book

This book is a subset of the *SOMobjects Developer Toolkit Users Guide* for the full-capability SOMobjects Developer Toolkit. The omitted chapters describe capabilities not included with the SOMobjects Base Toolkit. Chapters that are included appear in their entirety, as written for the full-capability SOMobjects system, except for some references to chapters/capabilities not included in the SOMobjects Base Toolkit. Because the current manual is a subset, references herein to the "SOMobjects Developer Toolkit" should be interpreted as referencing capabilities of the SOMobjects Base Toolkit.

Chapter 2 contains a Tutorial with six examples that illustrate techniques for implementing classes in SOM. *All* readers should cover this tutorial.

Chapter 3 describes how an application program creates instances of a SOM class, how it invokes methods, and so on. For readers interested only in *using* SOM classes, rather than building them, chapters 2 and 3 may provide all of the information they need to begin using SOM classes.

Chapter 4 provides more comprehensive information about the SOM system itself, including operation of the SOM run-time environment, method resolution, and inheritance. This chapter also describes how to create language-neutral class libraries using SOM, including explanations of valid syntax components. All class implementors will need to reference this chapter.

Chapter 5 deals with advanced topics for customizing SOM to better suit the needs of a particular application.

Chapter 6 describes **Distributed SOM** and how to use it to access objects across address spaces, even on different machines. Chapter 6 also describes how to customize DSOM. Note that SOMobjects Base Toolkit supports only *Workstation DSOM* (distribution among processes on a single machine), whereas SOMobjects Developer Toolkit also supports *Workgroup DSOM* (distribution among a network of machines).

Chapter 7 describes the **Interface Repository Framework** of classes supplied with the SOMobjects Toolkit.

Chapter 8 describes some utility metaclasses that SOM provides to assist users in deriving new classes with special abilities to execute "before" and "after" operations when a method call occurs.

Chapter 9 describes the **Event Management Framework**, which allows grouping of all application events and waiting on multiple events in one place. The Event Manager is used by both DSOM and the Replication Framework (the latter is not part of the SOMobjects Base Toolkit).

Appendix A describes service and technical support policies for the SOMobjects Toolkit, and contains lists of the error codes and messages that can be issued by the SOM kernel or by the included frameworks.

Appendix B contains the SOM IDL language grammar.

Appendix C describes how to subclass a "Sockets" class that facilitates inter-process communications required by the DSOM and Event Management Frameworks.

A Glossary and a thorough Index conclude this manual.

Chapter 2. Tutorial for Implementing SOM Classes

Contents

Chapter 2. Tutorial for Implementing SOM Classes

This tutorial contains six examples showing how SOM classes can be implemented to achieve various functionality. Obviously, for any person who wishes to become a class implementor, this tutorial is essential. However, even for those programmers who expect only to *use* SOM classes that were implemented by others, the tutorial is also necessary, as it presents several concepts that will help clarify the process of using SOM classes.

2.1 Basic Concepts of the System Object Model (SOM)

The **System Object Model (SOM),** provided by the **SOMobjects Developer Toolkit**, is a set of libraries, utilities, and conventions used to create binary class libraries that can be used by application programs written in various object-oriented programming languages, such as C++ and Smalltalk, or in traditional procedural languages, such as C and Cobol. The following paragraphs introduce some of the basic terminology used when creating classes in SOM:

- An *object* is an OOP entity that has *behavior* (its *methods* or operations) and *state* (its data values). In SOM, an object is a run-time entity with a specific set of methods and instance variables. The methods are used by a client programmer to make the object exhibit behavior (that is, to do something), and the instance variables are used by the object to store its state. (The state of an object can change over time, which allows the object's behavior to change.) When a method is invoked on an object, the object is said to be the *receiver* or *target* of the method call.

- An object's *implementation* is determined by the procedures that execute its methods, and by the type and layout of its instance variables. The procedures and instance variables that implement an object are normally *encapsulated* (hidden from the caller), so a program can use the object's methods without knowing anything about how those methods are implemented. Instead, a user is given access to the object's methods through its *interface* (a description of the methods in terms of the data elements required as input and the type of value each method returns).

- An interface through which an object may be manipulated is represented by an *object type*. That is, by declaring a type for an object variable, a programmer specifies the interface that is intended to be used to access that object. *SOM IDL* (the **SOM Interface Definition Language**) is used to define object interfaces. The *interface names* used in these IDL definitions are also the type names used by programmers when typing SOM object variables.

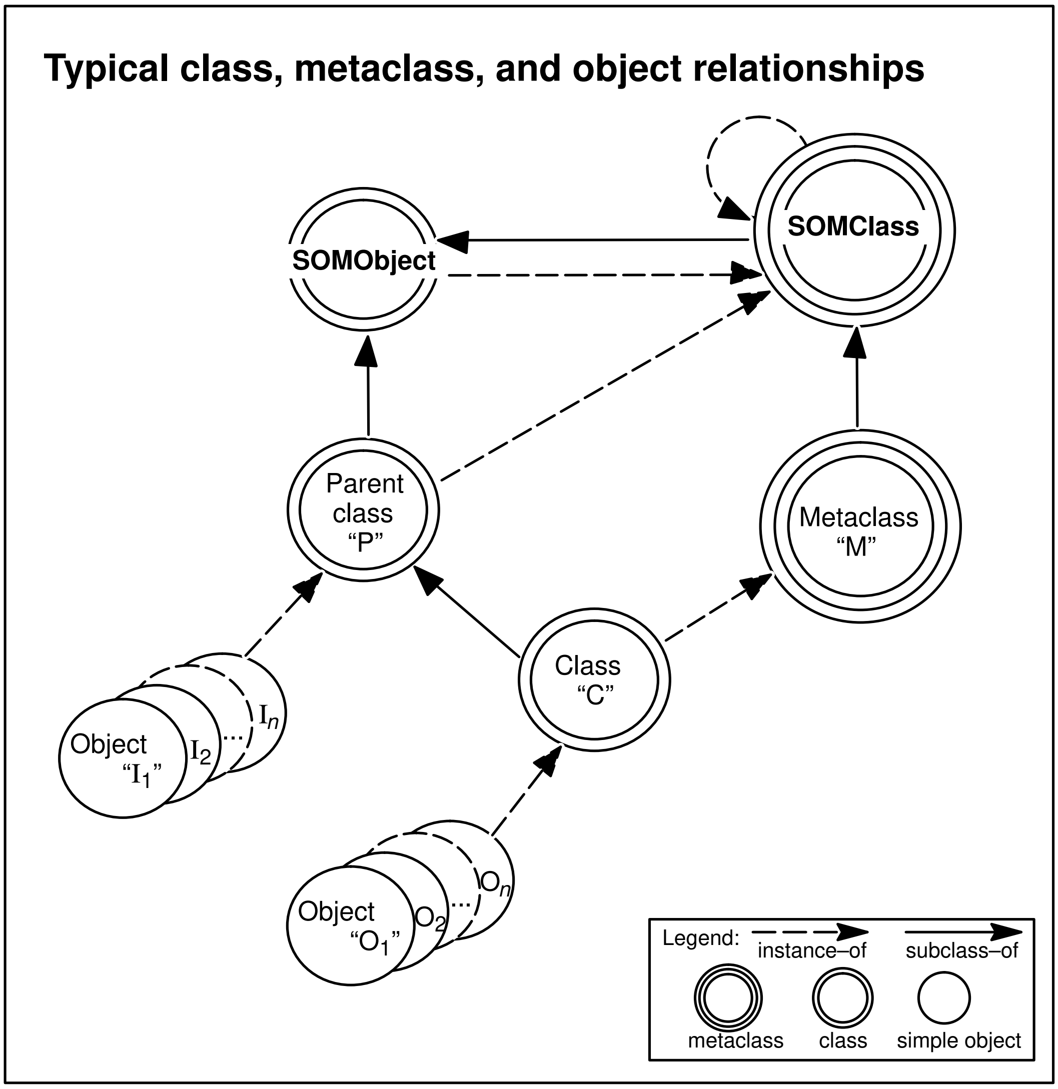
- In SOM, as in most approaches to object-oriented programming, a *class* defines the implementation of objects. That is, the implementation of any SOM object (as well as its interface) is defined by some specific SOM class. A class definition begins with an IDL specification of the interface to its objects, and the name of this interface is used as the class name as well. Each object of a given class may also be called an *instance* of the class, or an *instantiation* of the class.

- *Inheritance,* or *class derivation*, is a technique for developing new classes from existing classes. The original class is called the *base* class, or the *parent* class, or sometimes the direct *ancestor* class. The derived class is called a *child* class or a *subclass*. The primary advantage of inheritance is that a derived class inherits all of its parent's methods and instance variables. Also through inheritance, a new class can *override* (or redefine) methods of its parent, in order to provide enhanced functionality as needed. In addition, a derived class can introduce new methods of its own. If a class results from several generations of successive class derivation, that class “knows” all of its ancestors’s methods (whether overridden or not), and an object (or instance) of that class can execute any of those methods.

- SOM classes can also take advantage of *multiple inheritance,* which means that a new class is jointly derived from two or more parent classes. In this case, the derived class inherits methods from all of its parents (and all of its ancestors), giving it greatly expanded capabilities. In the event that different parents have methods of the same name that execute differently, SOM provides ways for avoiding conflicts.
- In the SOM run time, classes are themselves objects. That is, classes have their own methods and interfaces, and are themselves defined by other classes. For this reason, a class is often called a *class object*. Likewise, the terms *class methods* and *class variables* are used to distinguish between the methods/variables of a class object vs. those of its instances. (Note that the type of an object is *not* the same as the type of its class, which as a “class object” has its own type.)
- A class that defines the implementation of class objects is called a *metaclass*. Just as an instance of a class is an object, so an instance of a metaclass is a class object. Moreover, just as an ordinary class defines methods that its objects respond to, so a metaclass defines methods that a class object responds to. For example, such methods might involve operations that execute when a class (that is, a class object) is creating an instance of itself (an object). Just as classes are derived from parent classes, so metaclasses can be derived from parent metaclasses, in order to define new functionality for class objects.
- The SOM system contains three primitive classes that are the basis for all subsequent classes:

  SOMObject — the root ancestor class for all SOM classes,
  SOMClass — the root ancestor class for all SOM metaclasses, and
  SOMClassMgr — the class of the SOMClassMgrObject, an object created automatically during SOM initialization, to maintain a registry of existing classes and to assist in dynamic class loading/unloading.

  SOMClass is defined as a subclass (or child) of **SOMObject** and inherits all generic object methods; this is why instances of a metaclass are class *objects* (rather than simply classes) in the SOM run time. The adjacent figure illustrates typical relationships of classes, metaclasses, and objects in the SOM run time. (This illustration does not include the SOMClassMgrObject.)



SOM classes are designed to be *language neutral*. That is, SOM classes can be implemented in one programming language and used in programs of another language. To achieve language neutrality, the *interface* for a class of objects must be defined separately from its *implementation*. That is, defining interface and implementation requires two completely separate steps (plus an intervening compile), as follows:

- An *interface* is the information that a program must know in order to use an object of a particular class. This interface is described in an interface definition (which is also the class definition), using a formal language whose syntax is independent of the programming language used to implement the class's methods. For SOM classes, this is the SOM Interface Definition Language (SOM IDL). The interface is defined in a file known as the *IDL source file* (or, using its extension, this is often called the *.idl file*).

  An interface definition is specified within the *interface declaration* (or *interface statement*) of the .idl file, which includes:

  (a) the interface name (or class name) and the name(s) of the class's parent(s), and
  (b) the names of the class's attributes and the signatures of its new methods. (Recall that the complete set of available methods also includes all inherited methods.)

  Each *method signature* includes the method name, and the type and order of its arguments, as well as the type of its return value (if any). *Attributes* are instance variables for which "set" and "get" methods will automatically be defined, for use by the application program. (By contrast, instance variables that are not attributes are hidden from the user.)

- Once the IDL source file is complete, the *SOM Compiler* is used to analyze the .idl file and create the *implementation template file*, within which the class implementation will be defined. Before issuing the SOM Compiler command, **sc**, the class implementor can set an environment variable that determines which *emitters* (output-generating programs) the SOM Compiler will call and, consequently, which programming language and operating system the resulting *binding files* will relate to. (Alternatively, this emitter information can be placed on the command line for **sc.**) In addition to the implementation template file itself, the binding files include two language-specific header files that will be #included in the implementation template file and in application program files. The header files define many useful SOM macros, functions, and procedures that can be invoked from the files that include the header files.
- The *implementation* of a class is done by the class implementor in the *implementation template file* (often called just the *implementation file* or the *template file*). As produced by the SOM Compiler, the template file contains *stub procedures* for each method of the class. These are incomplete method procedures that the class implementor uses as a basis for implementing the class by writing the corresponding code in the programming language of choice.

In summary, the process of *implementing a SOM class* includes using the SOM IDL syntax to create an IDL source file that specifies the interface to a class of objects — that is, the methods and attributes that a program can use to manipulate an object of that class. The SOM Compiler is then run to produce an implementation template file and two binding (header) files that are specific to the designated programming language and operating system. Finally, the class implementor writes language-specific code in the template file to implement the method procedures.

At this point, the next step is to write the application (or client) program(s) that use the objects and methods of the newly implemented class. (Observe, here, that a programmer could write an application program using a class implemented entirely by someone else.) If not done previously, the SOM compiler is run to generate usage bindings for the new class, as appropriate for the language used by the client program (which may be different from the language in which the class was implemented). After the client program is finished, the programmer compiles and links it using a language-specific compiler, and then executes the program. (Notice again, the client program can invoke methods on objects of the SOM class without knowing how those methods are implemented.)

Development of the Tutorial examples

- **Example 1 — Implementing a simple class with one method**
  Prints a default message when the “sayHello” method is invoked on an object of the “Hello” class.
- **Example 2 — Adding an attribute to the Hello class**
  Defines a “msg” attribute for the “sayHello” method to use. The client program “sets” a message; then the “sayHello” method “gets” the message and prints it. (There is no defined message when an object of the “Hello” class is initialized.)
- **Example 3 — Overriding an inherited method**
  Overrides the required **somInit** method so the “msg” attribute will be “set” with default text as each instance of the “Hello” class is initialized. The client program can use that message and/or “set” it to a different one. As before, the “sayHello” method then “gets” the message and prints it.
- **Example 4 — Using metaclasses**
  Defines the metaclass “M_Hello” of the “Hello” class, plus a new metaclass method (“HelloCreate”) that is invoked on a “Hello” class object to create an instance (or object) of the “Hello” class. The client program first initializes the “Hello” class object. Then, when the new “HelloCreate” method is invoked, the call includes an argument containing text that “sets” the “msg” attribute when an object of the “Hello” class is created. Thus, the “Hello” object is initialized with a “msg” of the client’s choice.
- **Example 5 — Using metaclasses as counters**
  Does everything from Example 4, and extends it with an attribute (“numberObjs”) for the “HelloCreate” method of the metaclass. The “numberObjs” attribute increments a counter each time a call to the “HelloCreate” method creates a new object of the “Hello” class. The client program also adds a print statement to report how many objects of the “Hello” class are created.
- **Example 6 — Using multiple inheritance**
  Does everything from Example 5, and extends it to provide the “Hello” class with multiple inheritance (from the “Disk” and “Printer” classes). The “Hello” interface defines an enum and an “output” attribute that takes its value from the enum (either “screen”, “printer”, or “disk”). The client program “sets” the form of “output” before invoking the “sayHello” method to send a “msg” (defined as in Examples 4 and 5).

2.2 Basic Steps for Implementing SOM Classes

Implementing and using SOM classes in C or C++ involves the following steps, which are explicitly illustrated in the examples of this tutorial:

5. Define the interface to objects of the new class (that is, the interface declaration), by creating a **.idl** file.
6. Run the SOM Compiler on the .idl file (by issuing the **sc** command on AIX or OS/2, or by issuing the **somc** command on Windows) to produce the following binding files:
   - Template implementation file
     a **.c** file for C programmers, or
     a **.C** file (on AIX) or a **.cpp** file (on OS/2 or Windows) for C++ programmers;
   - Header file to be included in the implementation file
     a **.ih** file for C programmers, or
     a **.xih** file for C++ programmers; and
   - Header file to be included in client programs that use the class
     a **.h** file for C clients, or
     a **.xh** file for C++ clients.

   To specify whether the SOM Compiler should produce C or C++ bindings, set the value of the SMEMIT environment variable or use the "**–s**" option of the **sc** or **somc** command, as described in Section 4.6, "The SOM Compiler." By default, the SOM Compiler produces C bindings.
7. Customize the implementation, by adding code to the template implementation file.
8. Create a client program that uses the class.
9. Compile and link the client code with the class implementation, using a C or C++ compiler.
10. Execute the client program.

The following examples illustrate appropriate syntax for defining interface declarations in a .idl file, including designating the methods that the class's instances will perform. In addition, example template implementation files contain typical code that the SOM Compiler produces. Explanations accompanying each example discuss topics that are significant to the particular example; full explanations of the SOM IDL syntax are contained in Chapter 4, "Implementing Classes in SOM." Customization of each implementation file (step 3) is illustrated in both C and C++.

Example 1 — Implementing a Simple Class with One Method

Example 1 defines a class “Hello” which introduces one new method, “sayHello”. When invoked from a client program, the “sayHello” method will print the fixed string “Hello, World!” The example follows the six steps described in the preceding topic, “Basic Steps for Implementing SOM Classes.”

1) Define the interface to class “Hello”, which inherits methods from the root class **SOMObject** and introduces one new method, “sayHello”. Define these IDL specifications in the file “hello.idl”.

   The “interface” statement introduces the name of a new class and any parents (base classes) it may have (here, the root class **SOMObject**). The body of the interface declaration introduces the method “sayHello.” Observe that method declarations in IDL have syntax similar to C and C++ function prototypes:

```
#include <somobj.idl>  //# Get the parent class definition.

interface Hello : SOMObject
/*  This is a simple class that demonstrates how to define the
 *  interface to a new class of objects in SOM IDL.
 */
{
    void sayHello();
    // This method outputs the string ”Hello, World!”.
};
```

   Note that the method “sayHello” has no (explicit) arguments and returns no value. The characters “//” start a line comment, which finishes at the end of the line. The characters “/*” start a block comment which finishes with the “*/”. Block comments do not nest. The two comment styles can be used interchangeably. Throw-away comments are also permitted in a .idl file; they are ignored by the SOM Compiler. Throw-away comments start with the characters “//#” and terminate at the end of the line.

   Note: For simplicity, this IDL fragment does not include a **releaseorder** modifier; consequently, the SOM Compiler will issue a warning for the method “sayHello”. For directions on using the **releaseorder** modifier to remove this warning, see the topic “Modifier statements” in Chapter 4, “Implementing Classes in SOM”)

2) Run the SOM Compiler to produce binding files and an implementation template. That is, issue the **sc** command on AIX or OS/2, as follows:

```
> sc ”–sc;h;ih” hello.idl       (for C bindings on AIX or OS/2)

> sc ”–sxc;xh;xih” hello.idl    (for C++ bindings on AIX or OS/2)
```

   On Windows, issue the **somc** command (started from the Run option on the File menu):

```
> somc –sc;h;ih hello.idl       (for C bindings on Windows)

> somc –sxc;xh;xih hello.idl    (for C++ bindings on Windows)
```

   When set to generate C binding files, the SOM Compiler generates the following implementation template file, named “hello.c”, which contains *stub procedures* for each new method (procedures whose bodies are largely vacuous, to be filled in by the implementor). Unimportant details have been removed.

```
#include <hello.ih>

/*
 *  This method outputs the string "Hello, World!".
 */

SOM_Scope void   SOMLINK sayHello(Hello somSelf, Environment *ev)
{
    /* HelloData *somThis = HelloGetData(somSelf); */
    HelloMethodDebug("Hello", "sayHello");
}
```

The terms SOM_Scope and SOMLINK appear in the prototype for all stub procedures, but they are defined by SOM and are not of interest to the developer. In the method procedure for the "sayHello" method, "somSelf" is a pointer to the target object (here, an instance of the class "Hello") that will respond to the method. A "somSelf" parameter appears in the procedure prototype for every method, since SOM requires every method to act on some object.

The *target object* is always the first parameter of a method's procedure, although it should *not* be included in the method's IDL specification. The second parameter (which also is not included in the method's IDL specification) is the parameter **(Environment *ev)**. This parameter can be used by the method to return exception information if the method encounters an error. (Contrast the prototype for the "sayHello" method in steps 1 and 2 above.)

The remaining lines of the template above are not pertinent at this point. (For those interested, they are discussed in section 4.7 of Chapter 4, "Implementing SOM Classes.") The file is now ready for customization with the C code needed to implement method "sayHello".

When set to generate C++ binding files, the SOM Compiler generates an implementation template file, "hello.C" (on AIX) or "hello.cpp (on OS/2 or Windows), similar to the one above. (Chapter 4 discusses the implementation template in more detail.)

Recall that, in addition to generating a template implementation file, the SOM Compiler also generates implementation bindings (in a header file to be included in the implementation file) and usage bindings (in a header file to be included in client programs). These files are named "hello.ih" and "hello.h" for C bindings, and are "hello.xih" and "hello.xh" for C++ bindings. Notice that the "hello.c" file shown above includes the "hello.ih" implementation binding file.

3) Customize the implementation, by adding code to the template implementation file.

   Modify the body of the "sayHello" method procedure in the "hello.c" (or, for C++,"hello.C" on AIX, "hello.cpp" on OS/2) implementation file so that the "sayHello" method prints "Hello, World!":

```
SOM_Scope void   SOMLINK sayHello(Hello somSelf, Environment *ev)
{
    /* HelloData *somThis = HelloGetData(somSelf); */
    HelloMethodDebug("Hello","sayHello");

    printf("Hello, World!\n");
}
```

4) Create a client program that uses the class.

   Write a program "main" that creates an instance (object) of the "Hello" class and invokes the method "sayHello" on that object.

A C programmer would write the following program in “main.c”, using the bindings defined in the “hello.h” header file:

```
#include <hello.h>

int main(int argc, char *argv[])
{
    /* Declare a variable to point to an instance of Hello */
    Hello obj;

    /* Create an instance of the Hello class */
    obj = HelloNew();

    /* Execute the "sayHello" method */
    _sayHello(obj, somGetGlobalEnvironment());

    /* Free the instance: */
    _somFree(obj);
    return (0);
}
```

Notice the statement `obj = HelloNew();` The “hello.h” header file automatically contains the SOM-defined macro <*className*>**New()**, which is used to create an instance of the <*className*> class (here, the “Hello” class).

Also notice that, in C, a method is invoked on an object by using the form:

_<*methodName*> **(**<*objectName*>, <*environment_argument*>, <*other_method_arguments*>**)**

as used above in the statement `_sayHello(obj, somGetGlobalEnvironment())`. As shown in this example, the SOM-provided **somGetGlobalEnvironment** function can be used to supply the (**Environment** *) argument of the method.

Finally, the code uses the method **somFree**, which SOM also provides, to free the object created by `HelloNew()`. Notice that **somFree** does not require an (**Environment ***) argument. This is because the method procedures for some of the classes in the SOMobjects Toolkit (including **SOMObject**, **SOMClass**, and **SOMClassMgr**) do not have an Environment parameter, to ensure compatibility with the previous release of SOM. The documentation for each SOM-kernel method in the *SOMobjects Developer Toolkit: Programmers Reference Manual* indicates whether an Environment parameter is used.

A C++ programmer would write the following program in “main.C” (on AIX) or “main.cpp” (on OS/2), using the bindings defined in the “hello.xh” header file:

```
#include <hello.xh>

int main(int argc, char *argv[])
{
    /* Declare a variable to point to an instance of Hello */
    Hello *obj;

    /* Create an instance of the Hello class */
    obj = new Hello;

    /* Execute the "sayHello" method */
    obj->sayHello(somGetGlobalEnvironment());

    obj->somFree();
    return (0);
}
```

Notice that the only argument passed to the “sayHello” method by a C++ client program is the **Environment** pointer. (Contrast this with the invocation of “sayHello” in the C client program, above.

5) Compile and link the client code with the class implementation.

   Note: On AIX or OS/2, the environment variable SOMBASE represents the directory in which SOM has been installed.

   Under AIX, for C programmers:

```
> xlc –I. –I$SOMBASE/include –o hello main.c hello.c \
      –L$SOMBASE/lib –lsomtk
```

   Under AIX, for C++ programmers:

```
> xlC –I. –I$SOMBASE/include –o hello main.C hello.C \
      –L$SOMBASE/lib –lsomtk
```

   Under OS/2, for C programmers:

```
> set LIB=%SOMBASE%\lib;%LIB%
> icc –I. –I%SOMBASE%\include –Fe hello main.c hello.c \
      somtk.lib
```

   Under OS/2, for C++ programmers:

```
> set LIB=%SOMBASE%\lib;%LIB%
> icc –I. –I\%SOMBASE%\include –Fe hello main.cpp hello.cpp \
      somtk.lib
```

   Under Windows, for C programmers**:**

```
> cl –AL –Zp –D_WIN16 –F 5 –I. –I%SOMBASE%\include \
     –Fehello main.c hello.c llibcew.lib libw.lib somtk.lib
```

   where %SOMBASE% is replaced by the directory in which SOM was installed (the default is c:\som). In makefiles, the expression $(SOMBASE) can be used. Note that the –F option to set the stack size is unnecessary if STACKSIZE is specified in a .def file.

   Under Windows, for C++ programmers:

```
> cl –ALu –Zp –D_WIN16 –F 5 –I. –I%SOMBASE%\include \
     –Fehello main.cpp hello.cpp llibcew.lib libw.lib somtk.lib
```

   where %SOMBASE% is replaced by the directory in which SOM was installed (the default is c:\som). In makefiles, the expression $(SOMBASE) can be used. Note that the –F option to set the stack size is unnecessary if STACKSIZE is specified in a .def file.

6) Execute the client program.

```
> hello
Hello, World!
```

Example 2 will extend the “Hello” class to introduce an “attribute”.

File extensions for SOM files

- **IDL source file:**

.idl	for all users

- **Implementation template file:**

.c	for C, all systems
.C	for C++, on AIX
.cpp	for C++, on OS/2 or Windows

- **Header file for implementation file:**

.ih	for C
.xih	for C++

- **Header file for program file:**

.h	for C
.xh	for C++

Example 2 — Adding an Attribute to the Hello class

Example 1 introduced a class "Hello" which has a method "sayHello" that prints the fixed string "Hello, World!" Example 2 extends the "Hello" class so that clients can customize the output from the method "sayHello".

1) Modify the interface declaration for the class definition in "hello.idl."

   Class "Hello" is extended by adding an attribute that we call "msg". Declaring an *attribute* is equivalent to defining "get" and "set" methods. For example, specifying:

```
attribute string msg;
```

   is equivalent to defining the two methods:

```
string _get_msg();
void  _set_msg(in string msg);
```

   Thus, for convenience, an attribute can be used (rather than an instance variable) in order to use the automatically defined "get" and "set" methods <u>without having to write their method procedures</u>. The new interface specification for "Hello" that results from adding attribute "msg" to the "Hello" class is as follows (with some comment lines omitted):

```
#include <somobj.idl>

interface Hello : SOMObject
{
  void  sayHello();

  attribute string msg;
   //# This is equivalent to defining the methods:
   //#     string _get_msg();
   //#      void  _set_msg(string msg);
};
```

2) Re-run the SOM Compiler on the updated .idl file, as in example 1. This produces new header files and updates the existing implementation file, if needed, to reflect changes made to the .idl file. In this example, the implementation file is not modified by the SOM Compiler.

3) Customize the implementation.

   Customize the implementation file by modifying the print statement in the "sayHello" method procedure. This example prints the contents of the "msg" attribute (which must be initialized in the client program) by invoking the "_get_msg" method. Notice that, because the "_get_msg" method name begins with an underscore, the method is invoked with *two* leading underscores (for C only).

```
SOM_Scope void   SOMLINK sayHello(Hello somSelf, Environment *ev)
{
    /* HelloData *somThis = HelloGetData(somSelf); */
    HelloMethodDebug("Hello", "sayHello");

    printf("%s\n", __get_msg(somSelf, ev));

    /* for C++, use  somSelf->_get_msg(ev);  */
}
```

   This implementation assumes that "_set_msg" has been invoked to initialize the "msg" attribute before the "_get_msg" method is invoked by the "sayHello" method. This initialization can be done within the client program.

4) Update the client program.

Modify the client program so that the "_set_msg" method is invoked to initialize the "msg" attribute before the "sayHello" method is invoked. Notice that, because the "_set_msg" method name begins with an underscore, the C client program invokes the method with *two* leading underscores.

For C programmers:

```
#include <hello.h>

int main(int argc, char *argv[])
{
    Hello obj;

    obj = HelloNew();

    /* Set the msg text */
    __set_msg(obj, somGetGlobalEnvironment(), "Hello World Again");

    /* Execute the "sayHello" method */
    _sayHello(obj, somGetGlobalEnvironment());

    _somFree(obj);
    return (0);
}
```

For C++ programmers:

```
#include <hello.xh>

int main(int argc, char *argv[])
{
    Hello *obj;
    obj = new Hello;

    /* Set the msg text */
    obj->_set_msg(somGetGlobalEnvironment(), "Hello World Again");

    /* Execute the "sayHello" method */
    obj->sayHello(somGetGlobalEnvironment());

    obj->somFree();
    return (0);
}
```

5) Compile and link the client program, as before.

6) Execute the client program:

```
> hello
Hello World Again
```

The next example extends the "Hello" class to override (redefine) one of the methods it inherits from its parent class, **SOMObject**.

Example 3 — Overriding an Inherited Method

As defined in Example 2, the “Hello” class has the limitation that it relies on the client program to initialize the “msg” attribute of an object before the “sayHello” method is invoked on that object. This example extends the class so that the “sayHello” method behaves reasonably even without client initialization of the “msg” attribute. Specifically, this example initializes the “msg” attribute as the object is created.

By default, the SOM method **somInit** is called once on every object as it is created, in order to initialize the object. Thus, to automatically initialize the “msg” attribute when an instance of the “Hello” class is created, the “Hello” class *overrides* (redefines) the SOM method **somInit**, which the “Hello” class inherits from its designated parent class, **SOMObject**.

1) Modify the interface declaration in “hello.idl.”

To override the **somInit** method in “Hello”, additional information must be provided in “hello.idl” in the form of an **implementation** statement, which gives extra information about the class, its methods and attributes, and any instance variables. (The previous examples omitted the optional “implementation” statement, because it was not needed.)

In the current example, the “implementation” statement introduces the *modifiers* for the “Hello” class, as follows.

```
#include <somobj.idl>

interface Hello : SOMObject
{
  void sayHello();

  attribute string msg;

#ifdef __SOMIDL__
implementation
{
    //# Method Modifiers:
    somInit: override;
    // Override the inherited implementation of somInit.
};
#endif

};
```

Here, “somInit:” introduces a list of *modifiers* for the (inherited) **somInit** method in the class “Hello”. Modifiers are like C/C++ #pragma commands and give specific implementation details to the compiler. This example uses only one modifier, “override”. Because of the “override” modifier, when **somInit** is invoked on an instance of class “Hello”, Hello’s implementation of **somInit** (in the implementation file) will be called, instead of the implementation inherited from the parent class, **SOMObject**.

The “#ifdef __SOMIDL__” and “#endif” are standard C and C++ preprocessor commands that cause the “implementation” statement to be read only when using the SOM IDL compiler (and not some other IDL compiler).

2) Re-run the SOM Compiler on the updated .idl file, as before. The SOM Compiler extends the existing implementation file from Example 2 to include new stub procedures as needed (in this case, for **somInit**). Below is a shortened version of the C language implementation file as updated by the SOM Compiler; C++ implementation files are similarly revised. Notice that the code previously added to the “sayHello” method is not disturbed when the SOM Compiler updates the implementation file.

```
#include <hello.ih>

SOM_Scope void   SOMLINK sayHello(Hello somSelf, Environment *ev)
{
    /* HelloData *somThis = HelloGetData(somSelf); */
    HelloMethodDebug(”Hello”,”sayHello”);

    printf(”%s\n”, __get_msg(somSelf, ev));
}

SOM_Scope void   SOMLINK somInit(Hello somSelf)
{
    HelloData *somThis = HelloGetData(somSelf);
    HelloMethodDebug(”hello”,“somInit”);

    Hello_parent_SOMObject_somInit(somSelf);
}
```

Note that the SOM Compiler added code allowing the “Hello” class to redefine **somInit**. The SOM Compiler provides a default implementation for overriding the **somInit** method. This default implementation simply calls the “parent method” [the procedure that the parent class of “Hello” (**SOMObject**) uses to implement the **somInit** method]. This parent method call is accomplished by the invocation **`Hello_parent_SOMObject_somInit`**, which initializes any instance variables and attributes introduced by Hello’s parent class, **SOMObject**.

Notice that the stub procedure for overriding the **somInit** method does not include an Environment parameter. This is because **somInit** is introduced by **SOMObject**, which does not include the Environment parameter in any of its methods (to ensure backward compatibility). The signature for a method cannot change after it has been introduced.

3) Customize the implementation.

Within the new **somInit** method procedure, after invocation of the parent method, code is added to initialize the “msg” attribute as each instance of the “Hello” class is created:

```
SOM_Scope void   SOMLINK somInit(Hello somSelf)
{
    HelloData *somThis = HelloGetData(somSelf);
    HelloMethodDebug(”Hello”,”somInit”);

    Hello_parent_SOMObject_somInit(somSelf);
    __set_msg(somSelf, somGetGlobalEnvironment(), ”Hello, World!”);
    /*  for C++, use:
     * somSelf->_set_msg(somGetGlobalEnvironment(),”Hello, World!”);
     */
}
```

4) Update the client program.

The client program can now be restored to the original version, which doesn't initialize the "msg" attribute. Then, the client program can be modified to change the "msg" that will print and to invoke the "sayHello" method a second time.

For C programmers:

```
#include <hello.h>

int main(int argc, char *argv[])
{
    Hello obj;
    Environment *ev = somGetGlobalEnvironment();

    obj = HelloNew();

    _sayHello(obj, ev);  /* Print the default message: */
    __set_msg(obj, ev, "Hello World Again"); /* Set new message: */

    _sayHello(obj, ev);

    _somFree(obj);
    return (0);
}
```

For C++ programmers:

```
#include <hello.xh>

int main(int argc, char *argv[])
{
    Hello *obj;
    Environment *ev = somGetGlobalEnvironment();

    obj = new Hello;

    obj->sayHello(ev);
    obj->_set_msg(ev, "Hello World Again");
    obj->sayHello(ev);

    obj->somFree();
    return (0);
}
```

5) Compile and link the client program, as before.

6) Execute the client program, which now outputs both messages:

```
> hello
Hello, World!
Hello World Again
```

Example 4 — Using Metaclasses

The previous example showed how to override **somInit** to set a default value for the “msg” attribute. It would also be convenient if a user could initialize “msg” to a particular value as each “Hello” object is created. This is one use of *metaclasses*.

Recall that a metaclass is the class that a class object (such as “Hello”) is an instance of. A metaclass defines the methods that a *class* uses to perform class-related operations. This includes such things as creating instances of the class, returning information about the class’s methods or parent classes, and other “supervisory” operations that the *class itself* performs — as opposed to methods that *instances* of the class will perform (instance methods are defined within the class’s .idl file or are inherited from its parent classes).

The default metaclass for every class is **SOMClass**. For example, **SOMClass** provides the **somNew** method that a class uses to create its instances. [The “HelloNew” procedure (used previously in the main program) invokes the **somNew** method on the “Hello” class object to create instances of the “Hello” class.] The current example, however, employs a different technique for creating objects — one that permits the user to specify an initial value for “msg”.

A metaclass must be used here in order to modify a class-related operation (that is, to change the way in which the “Hello” class creates its instances, so that the client program can specify an initial value for the newly-created object’s “msg” attribute). “Hello” obtains this class method from its metaclass “M_Hello”, where the method is defined.

In summary, this example illustrates defining a new method of the “M_Hello” metaclass that, when performed by the “Hello” class object, creates an instance of the “Hello” class and sets the value of that instance’s “msg” attribute to a specified text string. [The new method is declared in the “M_Hello” interface (step 1) and is implemented in the implementation file (step 2)]. This allows the value of the “msg” attribute to be initialized by the client as it creates each instance of the “Hello” class.

The client program then performs three main activities:

- Creates a “Hello” class object, which can perform the new class method defined by the metaclass.
- Creates instances of the “Hello” class, specifying the initial value for each instance’s “msg” attribute (done by calling the class method defined by the metaclass).
- Prints the value of each instance’s “msg” attribute (by invoking the “sayHello” method on each object).

The following example describes each step in more detail.

1) Modify the interface declaration in “hello.idl.”

The interface for the metaclass of “Hello” must be declared, just as for the “Hello” class. By convention, the metaclass of “Hello” is called “M_Hello.” The interface for “M_Hello” consists of a user-defined method, “HelloCreate”, that creates an instance of the “Hello” class and initializes the “msg” attribute to the specified value.

```
#include <somobj.idl>  //# Get the parent (base) class definition
#include <somcls.idl>  //# Get the parent metaclass class definition

interface Hello;                // Forward declaration of Hello since
                                // HelloCreate returns class ”Hello”
interface M_Hello : SOMClass    // The metaclass for Hello.
{
    Hello HelloCreate(in string message);
    //This method creates an instance of the Hello class and
    // uses the value of ”message” to initialize it.
};
```

```
interface Hello : SOMObject
{
    void sayHello();

    attribute string msg;

#ifdef __SOMIDL__

     implementation {

        //# Class Modifiers
        metaclass = M_Hello; //# Identify Hello's metaclass
    };
#endif    //# __SOMIDL__
};
```

In the “implementation” statement for the “Hello” interface, we have removed the earlier statement `somInit:override`, since “msg” will be initialized differently. Now, the “implementation” statement for “Hello” designates the metaclass of “Hello” by using the “metaclass” modifier with a value of “M_Hello”. (If not explicitly specified, the metaclass of a class is derived from its parents.)

As shown in this example, the “interface” statements for a class and its metaclass may appear in the same .idl file. IDL also allows the interfaces to arbitrary sets of classes to be defined in the same .idl file; however, if the classes are not a class-metaclass pair, then the “interface” statements should be contained in a **module** statement. Chapter 4, “Implementing SOM Classes” contains a section entitled “SOM Interface Definition Language” that describes the use of modules in IDL.

2) Re-run the SOM Compiler on the updated .idl file, as before. The SOM Compiler extends the existing implementation file to include stub procedures for methods added for the class's metaclass, as specified by M_Hello's interface declaration. Below is the material that the SOM Compiler adds to the C language implementation file; C++ implementation files are similarly revised:

```
#include <hello.ih>

SOM_Scope void   SOMLINK sayHello(Hello somSelf, Environment *ev)
{
    /* HelloData *somThis = HelloGetData(somSelf); */
    HelloMethodDebug("Hello","sayHello");

    printf("%s\n", __get_msg(somSelf, ev));
}

/*
 *  This method creates an instance of the Hello class and
 *  uses the value of "message" to initialize it.
 */
SOM_Scope Hello SOMLINK HelloCreate(M_Hello somSelf,
                                Environment *ev, string message)
{
    /* M_HelloData *somThis = M_HelloGetData(somSelf) ; */
    M_HelloMethodDebug("M_Hello","HelloCreate") ;

    /* Return statement to be customized: */
    return;
}
```

3) Customize the implementation.

Expand the “HelloCreate” method procedure as follows:

```
SOM_Scope Hello SOMLINK HelloCreate(M_Hello somSelf,
                                Environment *ev, string message)
{
    /* M_HelloData *somThis = M_HelloGetData(somSelf) ; */
    Hello obj = _somNew(somSelf) ;
        /* for C++, use:   somSelf->somNew()   */
    M_HelloMethodDebug("M_Hello","HelloCreate") ;

    __set_msg(obj, ev, message) ;
        /* for C++, use:  obj->_set_msg(ev, message);  */
    return (obj) ;
}
```

“HelloCreate” invokes the method **somNew** (provided by **SOMClass**) to create an instance of the “Hello” class. It then sets the value of the “msg” attribute by invoking the “_set_msg” method (similarly to Example 2 in the *client* program).

4) Update the client program.

The client program can now call the “HelloCreate” method to create an instance of the “Hello” class and set the “msg” attribute at the same time. This implementation is illustrated with the following C client program (a corresponding C++ example is also given following the explanatory paragraphs for step 4):

```
#include <hello.h>

int main(int argc, char *argv[])
{
    Hello a, b, c;
    Environment *ev = somGetGlobalEnvironment();

    /*
    * Create the Hello Class and save a pointer to it.
    * The class of a Hello class object is M_Hello.
    */
    M_Hello helloClsObj = HelloNewClass(Hello_MajorVersion,
                                        Hello_MinorVersion) ;

    /* Now create three instances of the Hello class */
    a = _HelloCreate(helloClsObj, ev, "Hello from A") ;
    b = _HelloCreate(helloClsObj, ev, "Hello from B") ;
    c = _HelloCreate(helloClsObj, ev, "Hello from C") ;

    /* Now call sayHello on each object */
    _sayHello(a, ev) ;
    _sayHello(b, ev) ;
    _sayHello(c, ev) ;

    _somFree(a) ;
    _somFree(b) ;
    _somFree(c) ;
    return (0);
}
```

The client program first creates the “Hello” class object (`helloClsObj`), by calling the “HelloNewClass” procedure. The “HelloNewClass” procedure is defined by the SOM Compiler in the “hello.h” or “hello.xh” header file for the “Hello” class. (The SOM Compiler defines a <className>**NewClass** procedure for each class, in the header file it generates for the class.) In addition to creating the “Hello” class object, this procedure also creates the class objects for the parent classes and metaclass of “Hello”.

Previous examples did not explicitly call the “HelloNewClass” procedure, because it is called by the “HelloNew” macro. In this example, however, the client program must explicitly create the “Hello” class object, so that it can invoke the new “HelloCreate” method on it.

Note: The “Hello_MajorVersion” and “Hello_MinorVersion” arguments to “HelloNewClass” are defined in the header file for the “Hello” class by the SOM Compiler; they refer to the version numbers of the “Hello” class at the time the header file was produced. SOM ensures that the class object it creates is consistent with the specified version numbers.

After creating the “Hello” class object, the client program then creates three new instances of the “Hello” class and invokes the “sayHello” method on each one.

The following code illustrates the revised client program in C++.

```
#include <hello.xh>
#include <stdio.h>

int main(int argc, char *argv[])
{
    Hello *a, *b, *c;
    Environment *ev = somGetGlobalEnvironment();

    /*
     * Create the Hello class object, and save a pointer to it.
     * The class of a Hello class object is M_Hello.
     */
    M_Hello *helloClsObj = HelloNewClass(Hello_MajorVersion,
                                         Hello_MinorVersion);

    /* Create three different instances of the Hello class object. */
    a = helloClsObj->HelloCreate(ev, "Hello from A");
    b = helloClsObj->HelloCreate(ev, "Hello from B");
    c = helloClsObj->HelloCreate(ev, "Hello from C");

    /* Now call sayHello on each object. */
    a->sayHello(ev);
    b->sayHello(ev);
    c->sayHello(ev);

    a->somFree();
    b->somFree();
    c->somFree();
    return (0);
}
```

5) Compile and link the client program, as before.

6) Execute the client program:

```
> hello
Hello from A
Hello from B
Hello from C
```

Example 5 — Using Metaclasses as Counters

The previous example introduced metaclasses as a way to provide *constructors* (methods for creating new instances of a class). Metaclasses are also useful for providing methods that maintain information about all the objects of a particular class. One simple use of metaclasses is to maintain a count of all of the objects that a class creates. This example does everything that Example 4 did, and also counts the number of objects created.

1) Modify the interface declaration in "hello.idl" so that it provides an attribute for the "Hello" class object to count the number of objects it creates.

```
#include <somobj.idl>
#include <somcls.idl>

interface Hello;               // Forward declaration of Hello since
                               // HelloCreate returns class "Hello"
interface M_Hello : SOMClass   // The meta class for Hello.
{
    Hello HelloCreate(in string message);
    //This method creates an instance of the Hello class and
    // uses the value of "message" to initialize it.

    readonly attribute long numberObjs;
};

interface Hello : SOMObject
{
    void sayHello();

    attribute string msg;

#ifdef __SOMIDL__

     implementation {

         //# Class Modifiers
         metaclass = M_Hello; //# Identify Hello's metaclass
    };
#endif    //# __SOMIDL__
};
```

The "readonly" keyword means that only a "_get_numberObjs" method will be defined, and not a "_set_numberObjs". (A "_set_numberObjs" method is not needed because clients should not be permitted to change the value of the "numberObjs" attribute.) The implementation of the class can access the attribute by accessing its corresponding *instance variable*. Internal instance variables are automatically defined to store an attribute's data. (An exception is attributes given the "nodata" SOM IDL attribute modifier, described in Chapter 4, "Implementing SOM Classes.)

2) Re-run the SOM Compiler on the updated .idl file, as before.
   (In this case, the implementation file does not require modification.)

3) Customize the implementation.

   Given the "readonly" attribute for "numberObjs", modify the "HelloCreate" method to increment "numberObjs" every time a client invokes "HelloCreate". Notice that the assignment statement for **somThis** below has been uncommented as well. This is necessary because the implementation of the “HelloCreate” method accesses the “numberObjs” attribute via the corresponding “numberObjs” instance variable. The assignment to **somThis** must be made before a method implementation can access instance variables of the class.

```
SOM_Scope Hello  SOMLINK HelloCreate(M_Hello somSelf,
                         Environment *ev, string message)
{
    M_HelloData *somThis = M_HelloGetData(somSelf) ;
    Hello obj = _somNew(somSelf) ;
        /* for C++, use:   somSelf->somNew()  */
    M_HelloMethodDebug("M_Hello","HelloCreate") ;

    __set_msg(obj, ev, message) ;
        /* for C++, use obj->_set_msg(ev, message) ;   */
    (somThis->numberObjs)++ ;
    return (obj) ;
}
```

The syntax `somThis->numberObjs` is used to set the value of the “numberObjs” attribute in the absence of a “set” method. In general, the implementation file for a class can access any instance variable of the class via the **somThis–>***variableName* macro, or by the shorthand form, _*variableName*. (In C++, the shorthand form is only available if VARIABLE_MACROS is defined (via a #define directive) in the implementation file prior to including the .xih file.)

4) Update the client program.

The client program can now report the number of “Hello” objects created during its lifetime, as in the following C program (the Example 4 code with a print statement added):

```
#include <hello.h>
        /* for C++, use "hello.xh". */

int main(int argc, char *argv[])
{
    Hello a, b, c;
    Environment *ev = somGetGlobalEnvironment();

    /*
    * Create the Hello Class and save a pointer to it.
    * The class of a Hello class object is M_Hello.
    */
    M_Hello helloClsObj = HelloNewClass(Hello_MajorVersion,
                                        Hello_MinorVersion) ;

    /* Now create an instance of the Hello class */
    a = _HelloCreate(helloClsObj, ev, "Hello from A") ;
            /* for C++, use:
               a = helloClsObj->HelloCreate(ev, "Hello from A");  */
    b = _HelloCreate(helloClsObj, ev, "Hello from B") ;
    c = _HelloCreate(helloClsObj, ev, "Hello from C") ;

    /* Now call sayHello on each object */
    _sayHello(a, ev) ;   /* for C++, use:  a->sayHello(ev);  */
    _sayHello(b, ev) ;
    _sayHello(c, ev) ;

    printf("# objs created: %ld\n",
                            __get_numberObjs(helloClsObj, ev) );

          /*  for C++, use:  helloClsObj->_get_numberObjs(ev);  */
```

```
    _somFree(a) ;  /* for C++, use: a->somFree(); */
    _somFree(b) ;
    _somFree(c) ;
    return (0);
}
```

5) Compile and link the client program, as before.

6) Execute the client program:

```
> hello
Hello from A
Hello from B
Hello from C
# objs created: 3
```

Attributes vs instance variables

As an alternative to defining “numberObjs” as an attribute, it could be defined as an instance variable, with a “get_numberObjs” method also defined for retrieving its value, as shown below:

```
interface M_Hello
//  The metaclass for Hello.
{
  Hello HelloCreate(in string message) ;
  // This method creates an instance of the Hello class and
  // uses the value of "message" to initialize it.

    long get_numberObjs() ;

#ifdef __SOMIDL__
implementation
{
    long numberObjs;
};
#endif
};
```

The disadvantage to using an instance variable is that the “get_numberObjs” method must be defined in the implementation file by the class implementor. For attributes, by contrast, default implementations of the “get” and “set” methods are generated automatically by the SOM Compiler in the .ih and .xih header files.

Note: For some attributes (particularly those involving structures, strings, and pointers) the default implementation generated by the SOM Compiler for the “set” method may not be suitable. This happens because the SOM Compiler only performs a “shallow copy,” which typically is not useful for distributed objects with these types of attributes. In such cases, it is possible to write your own implementations, as you do for any other method, by specifying the “noset/noget” modifiers for the attribute.

Regardless of whether you let the SOM Compiler generate your implementations or not, if access to instance data is required, either from a subclass or a client program, then this access should be facilitated by using an attribute. Otherwise, instance data can be defined in the “implementation” statement as above (using the same syntax with which variables are declared in C or C++), with appropriate methods defined to access it.

As an example where instance variables would be used (rather than attributes), consider a class “Date” that provides a method for returning the current date. Suppose the date is represented by three instance variables — “mm”, “dd”, and “yy”. Rather than making “mm”, “dd”, and “yy” attributes (and allowing clients to access them directly), “Date” defines “mm”, “dd”, and “yy” as instance variables in the “implementation” statement, and defines a method “get_date” that converts “mm”, “dd”, and “yy” into a string of the form “mm/dd/yy”:

```
interface Date
{
    string get_date() ;

#ifdef __SOMIDL__
implementation
{
    long mm,dd,yy;
};
#endif
};
```

To access instance variables that a class introduces from within the class implementation file, two forms of notation are available:

somThis–>variableName

or

_variableName

For example, the implementation for “get_date” would

access the “mm” instance variable as `somThis->mm` or `_mm`,
access “dd” as `somThis->dd` or `_dd`, and
access “yy” as `somThis->yy` or `_yy`.

In C++ programs, the *_variableName* form is available only if the programmer first defines the macro VARIABLE_MACROS (that is, enter `#define VARIABLE_MACROS`) in the implementation file prior to including the .xih file for the class.

Example 6 — Using Multiple Inheritance

The "Hello" class is useful for writing messages to the screen. So that clients can also write messages to printers and disk files, this example references two additional classes: "Printer" and "Disk". The "Printer" class will manage messages to a printer, and the "Disk" class will manage messages sent to files. These classes can be defined as follows (this example also retains all of the functionality of Example 5):

```
#include <somobj.idl>

interface Printer : SOMObject
{
    void stringToPrinter(in string s) ;
    // This method writes a string to a printer.
};

#include <somobj.idl>

interface Disk : SOMObject
{
    void stringToDisk(in string s) ;
    // This method writes a string to disk.

};
```

This example assumes the "Printer" and "Disk" classes are defined separately (in "print.idl" and "disk.idl", for example), are implemented in separate files, and are linked with the other example code. Given the implementations of the "Printer" and "Disk" interfaces, the "Hello" class can use them by inheriting from them, as illustrated next.

1) Modify the interface declaration in "hello.idl".

```
#include <somcls.idl>
#include <disk.idl>
#include <printer.idl>

interface Hello;

interface M_Hello : SOMClass
// The metaclass for Hello.
{
    Hello HelloCreate(in string message);
    // This method creates an instance of the Hello class and
    // uses the value of "message" to initialize it.

    readonly attribute long numberObjs;
};

interface Hello : Disk, Printer
{
    void sayHello();

    attribute string msg;

    enum outputTypes {screen, printer, disk};
    // Declare an enumeration for the different forms of output

    attribute outputTypes output;
    // The current form of output
```

```
#ifdef __SOMIDL__

  implementation {

      metaclass = M_Hello;
      override: somInit; //# Override somInit to call the somInit
                         //# method of each parent as it is created.
  };
#endif //#  __SOMIDL__
};
```

Notice that **SOMObject** is not listed as a parent of “Hello” above, because **SOMObject** is a parent of “Disk” (and of “Printer”).

The IDL specification above declares an enumeration “outputTypes” for the different forms of output, and an attribute “output” whose value will depend on where the client wants the output of the “sayHello” method to go.

Note: SOM IDL allows the use of structures, unions (though with a syntax different from C or C++), enumerations, constants, and typedefs, both inside and outside the body of an interface statement. Declarations that appear inside an interface body will be emitted in the header file (that is, in “hello.h” or “hello.xh”). Declarations that appear outside of an interface body do not appear in the header file (unless required by a special #pragma directive; see the SOM Compiler options in Chapter 4).

SOM IDL also supports all of the C and C++ preprocessor directives, including conditional compilation, macro processing, and file inclusion.

2) Re-run the SOM Compiler on the updated .idl file, as before.

3) Customize the implementation, as in the following “hello.c” file:

```
SOM_Scope void  SOMLINK sayHello(Hello somSelf, Environment *ev)
{
    /* HelloData *somThis = HelloGetData(somSelf) ; */
    HelloMethodDebug(”Hello”,”sayHello”) ;

    switch (__get_output(somSelf, ev) ) {
            /*  for C++, use:  somSelf->_get_output(ev) */
    case Hello_screen:
        printf(”%s\n”, __get_msg(somSelf, ev) );
            /*  for C++, use:  somSelf->_get_msg(ev) */
        break;
    case Hello_printer:
        _stringToPrinter(somSelf, ev, __get_msg(somSelf, ev) );
            /* for C++, use:
             * somSelf->stringToPrinter(ev, somSelf->_get_msg(ev) );
             */
        break;
    case Hello_disk:
        _stringToDisk(somSelf, ev, __get_msg(somSelf, ev) );
            /*  for C++, use:
             *   somSelf->stringToDisk(ev, somSelf->_get_msg(ev) );
             */
        break;
    }
}
```

The “switch” statement invokes the appropriate method depending on the value of the “output” attribute. Notice how the “case” statements utilize the enumeration values of “outputTypes” declared in “hello.idl” by prefacing the enumeration names with the class name (Hello_screen, Hello_printer, and Hello_disk).

Next, the implementation for “HelloCreate” is modified so that the “msg” output will go to the screen by default. Code in the client program can reassign output to the printer or to disk, as needed. In addition, we *must* override the **somInit** method for “Hello”, to ensure that all of the parent **somInit** methods are called.

```
SOM_Scope Hello  SOMLINK HelloCreate(M_Hello somSelf,
                                  Environment *ev, char *message)
{
    /* M_HelloData *somThis = M_HelloGetData(somSelf) ; */
    Hello obj = _somNew(somSelf) ;
        /* for C++, use:   somSelf->somNew()  */
    M_HelloMethodDebug(”M_Hello”,”HelloCreate”) ;

    __set_msg(obj, ev, message) ;
        /* for C++, use:  obj->_set_msg(ev, message) ;  */
    (somThis->numberObjs)++ ;
    __set_output(obj, ev, Hello_screen) ;
         /* for C++, use: obj->_set_output(ev, Hello_screen);  */
    return (obj) ;
}

SOM_Scope void  SOMLINK somInit(Hello *somSelf)
{
    /* HelloData *somThis = HelloGetData(somSelf); */
    HelloMethodDebug(”Hello”,”somInit”);

    Hello_parent_Disk_somInit(somSelf);
    Hello_parent_Printer_somInit(somSelf);
}
```

4) Update the client program, as illustrated next:

```
#include <hello.h>
        /* for C++, use ”hello.xh” and <stdio.h> */

int main(int argc, char *argv[])
{
    Hello a;
    Environment *ev = somGetGlobalEnvironment();

    /*
    * Create the Hello Class and save a pointer to it.
    * The class of a Hello class object is M_Hello.
    */
    M_Hello helloClsObj = HelloNewClass(Hello_MajorVersion,
                                        Hello_MinorVersion) ;

    /* Now create an instance of the Hello class object*/
    a = _HelloCreate(helloClsObj, ev, ”Hello from A”) ;
             /* for C++, use:
                a = helloClsObj->HelloCreate(ev, ”Hello from A”); */
```

```
    /* Now call sayHello on an object and use each output */
    _sayHello(a, ev) ;        /* for C++, use:  a->sayHello(ev);  */
    __set_output(a, ev, Hello_printer) ;
                     /* C++:   a->_set_output(ev, Hello_printer); */
    _sayHello(a, ev) ;
    __set_output(a, ev, Hello_disk) ;
                     /* C++:   a->_set_output(ev, Hello_disk);  */
    _sayHello(a, ev) ;

    printf("# objs created: %ld\n",
                            __get_numberObjs(helloClsObj, ev) );

         /*  for C++, use:  helloClsObj->_get_numberObjs(ev) ; */

    _somFree(a) ;  /* for C++, use: a->somFree(); */
    return (0);
}
```

5) Compile and link the client program, as before.

6) Execute the client program:

```
Hello from A
Hello from A              – goes to a Printer
Hello from A              – goes to Disk
# objs created: 1
```

This tutorial has described the features of SOM IDL that will be most useful to C and C++ programmers. SOM IDL also provides features such as full type checking, constructs for declaring private methods, and constructs for defining methods that receive and return pointers to structures. Chapter 4, "Implementing SOM Classes," gives a complete description of the SOM IDL syntax. That chapter also describes how to use the SOM Compiler and provides more complete information on implementing SOM class libraries.

Chapter 3. Using SOM Classes in Client Programs

Contents

Chapter 3. Using SOM Classes in Client Programs

This chapter discusses how to use SOM classes that have already been fully implemented. That is, these topics describe the steps that a programmer uses to instantiate an object and invoke some method(s) on it from within an application program.

Who should read this chapter?

- Programmers who wish to use SOM classes that were originally developed by someone else will need to know the information in this chapter. These programmers often may not need the information from any subsequent chapters.
- By contrast, class implementors who are creating their own SOM classes should continue with Chapter 4, “Implementing SOM Classes,” for complete information on the SOM Interface Definition Language (SOM IDL) syntax and other details of class implementation.

Programs that use a class are referred to as *client programs.* A client program can be written in C, in C++, or in another language. As noted, this chapter describes how client programs can use SOM classes (classes defined using SOM, as described in Chapter 2, “Tutorial for Implementing SOM Classes” and in Chapter 4, “Implementing SOM Classes”). Using a SOM class involves creating instances of a class, invoking methods on objects, and so forth. All of the methods, functions, and macros described here can also be used by class implementors within the implementation file for a class.

Note: “Using a SOM class,” as described in this chapter, does *not* include subclassing the class in a client program. In particular, the C++ compatible SOM classes made available in the .xh binding file can *not* be subclassed in C++ to create new C++ or SOM classes.

Some of the macros and functions described here are supplied as part of SOM’s C and C++ *usage bindings*. These bindings are functions and macros defined in header files to be included in client programs. The usage bindings make it more convenient for C and C++ programmers to create and use instances of SOM classes. SOM classes can be also used without the C or C++ bindings, however. For example, users of other programming languages can use SOM classes, and C and C++ programmers can use a SOM class without using its language bindings. The language bindings simply offer a more convenient programmer’s interface to SOM. Vendors of other languages may also offer SOM bindings; check with your language vendor for possible SOM support.

To use the C or C++ bindings for a class, a client program must include a header file for the class (using the **#include** preprocessor directive). For a C language client program, the file <*classFileStem*>.h must be included. For a C++ language client program, the file <*classFileStem*>.xh must be included. The SOM Compiler generates these header files from an IDL interface definition. The header files contain definitions of the macros and functions that make up the C or C++ bindings for the class. Whether the header files include bindings for the class’s private methods and attributes (in addition to the public methods and attributes) depends on the IDL interface definition available to the user, and on how the SOM Compiler was invoked when generating bindings.

Usage binding headers automatically include any other bindings upon which they may rely. Client programs not using the C or C++ bindings for any particular class of SOM object (for example, a client program that does not know at compile time what classes it will be using) should simply include the SOM-supplied bindings for **SOMObject**, provided in the header file “somobj.h” (for C programs) or “somobj.xh” (for C++ programs).

For each task that a user of a SOM class might want to perform, this chapter shows how the task would be accomplished by:

- a C programmer using the C bindings,
- a C++ programmer using the C++ bindings, or
- a programmer not using SOM’s C or C++ language bindings.

If neither of the first two approaches is applicable, the third approach can always be used.

3.1 An Example Client Program

Following is a C program that uses the class “Hello” (as defined in the Tutorial in Chapter 2). The “Hello” class provides one attribute, “msg”, of type string, and one method, “sayHello”. The “sayHello” method simply displays the value of the “msg” attribute of the object on which the method is invoked.

```
#include <hello.h>  /* include the header file for Hello */

int main(int argc, char *argv[])
{
    /* declare a variable (obj) that is a
     * pointer to an instance of the Hello class: */
    Hello obj;

    /* create an instance of the Hello class
     * and store a pointer to it in obj: */
    obj = HelloNew();

    /* invoke method _set_msg on obj with the argument
     * ”Hello World Again”. This method sets the value of
     * obj’s ’msg’ attribute to the specified string.
     */
    __set_msg(obj, somGetGlobalEnvironment(), ”Hello World Again”);

    /* invoke method sayHello on obj. This method prints
     * the value of obj’s ’msg’ attribute.  */
    _sayHello(obj, somGetGlobalEnvironment());

    return(0);
}
```

The C++ version of the foregoing client program is shown below:

```
#include <hello.xh>  /* include the header file for Hello */

int main(int argc, char *argv[])
{
    /* declare a variable (obj) that is a
     * pointer to an instance of the Hello class: */
    Hello *obj;

    /* create an instance of the Hello class
     * and store a pointer to it in obj: */
    obj = new Hello;

    /* invoke method _set_msg on obj with the argument
     * ”Hello World Again”. This method sets the value of
     * obj’s ’msg’ attribute to the specified string.  */
    obj–>_set_msg(somGetGlobalEnvironment(), ”Hello World Again”);

    /* invoke method sayHello on obj. This method prints
     * the value of obj’s ’msg’ attribute.  */
    obj–>sayHello(somGetGlobalEnvironment());

    return(0);
}
```

These client programs both produce the output:

```
Hello World Again
```

3.2 Using SOM Classes — the Basics

Declaring object variables

When declaring an object variable, an *object interface* name defined in IDL is used as the *type* of the variable. The exact syntax is slightly different for C vs. C++ programmers. Specifically,

<*interfaceName*> obj ;	in C programs or
<*interfaceName*> *obj ;	in C++ programs

declares "obj" to be a pointer to an object that has type <*interfaceName*>. In SOM, objects of this type are instances of the SOM *class* named <*interfaceName*>, or of any SOM class derived from this class. Thus, for example,

```
Animal obj;           in C programs or
Animal *obj;          in C++ programs
```

declares "obj" as pointer to an object of type "Animal" that can be used to reference an instance of the SOM class "Animal" or any SOM class derived from "Animal". Note that the type of an object need not be the same as its class*;* an object of type "Animal" might not be an instance of the "Animal" class (rather, it might be an instance of some subclass of "Animal" — the "Cat" class, perhaps).

All SOM objects are of type **SOMObject**, even though they may not be instances of the **SOMObject** class. Thus, if it is not known at compile time what type of object the variable will point to, the following declaration can be used:

```
SOMObject obj;        in C programs or
SOMObject *obj;       in C++ programs.
```

Because the sizes of SOM objects are not known at compile time, instances of SOM classes must always be dynamically allocated. Thus, a variable declaration must always define a pointer to an object.

Note: in the C usage bindings, as within an IDL specification, an interface name used as a type *implicitly* indicates a pointer to an object that has that interface (this is required by the CORBA specification). The C usage bindings for SOM classes therefore hide the pointer with a C typedef for <*interfaceName*>. But this is not appropriate in the C++ usage bindings, which define a C++ class for <*interfaceName*>. Thus, it is not correct in C++ to use a declaration of the form:

<*interfaceName*> obj ;   *not valid* in C++ programs

Note: If a C programmer also prefers to use explicit pointers to <*interfaceName*> types, then the SOM Compiler option **–maddstar** can be used when the C binding files are generated, and the explicit "*****" will then be required in declarations of object variables. (This option is required for compatibility with existing SOM OIDL code. For information on using the **–maddstar** option, see "Running the SOM Compiler" in Chapter 4, "Implementing SOM Classes.")

Users of other programming languages must also define object variables to be pointers to the data structure used to represent SOM objects. The way this is done is programming-language dependent. The header file "somitype.h" defines the structure of SOM objects for the C and C++ languages, and is included by the C and C++ usage bindings.

Creating instances of a class

For C programmers with usage bindings, SOM provides the <*className*>**New** and the <*className*>**Renew** macros for creating instances of a class.

These macros are illustrated with the following two examples, each of which creates a single instance of class “Hello”:

```
obj = HelloNew();
obj = HelloRenew(buffer);
```

Using <*className*> New

The <*className*>**New** macro allocates enough space for a new instance of <*className*>, creates a new, initialized class instance, and returns a pointer to it. The <*className*>**New** macro automatically creates the class object for <*className*>, as well as its ancestor classes and metaclass, if needed.

After a client program has finished using an object created using the <*className*>**New** macro, the object should be freed by invoking the method **somFree** on it :

```
_somFree(obj);
```

This is important because storage for an object created using the <*className*>**New** macro is allocated by the class of the object. Because only the class of an object created this way can know how to reclaim the object’s storage, the **somFree** method is designed to call the class object for storage deallocation.

Using <*className*> Renew

The <*className*>**Renew** macro is only used when the space for the object has been allocated previously. (Perhaps the space holds an old object that is not needed anymore.) This macro converts the given space into a new, initialized instance of <*className*> and returns a pointer to it. The argument of <*className*>**Renew** must point to a block of storage large enough to hold an instance of class <*className*>. The SOM method **somGetInstanceSize** can be invoked on the class to determine the amount of memory required.

Hint: When creating a large number of class instances, it may be more efficient to allocate at once enough memory to hold all the instances, and then invoke <*className*>**Renew** once for each object to be created, rather than performing separate memory allocations.

In addition, use of the<*className*>**Renew** macro requires that the class object has already been created (otherwise an error will result). The C and C++ usage bindings for a SOM class provide static linkage to a <*className*>**NewClass** procedure that can be used to create the class object.

For example, the following C code uses the function **HelloNewClass** to create the “Hello” class object. The arguments to this function are defined by the usage bindings, and indicate the version of the class implementation that is assumed by the bindings. (For more detail on creation of classes, see the later section, “Creating a class object.”) Once the class object has been created, the example invokes the method **somGetInstanceSize** on this class to determine the size of a “Hello” object, uses **SOMMalloc** to allocate storage, and then uses the **HelloRenew** macro to create ten instances of the “Hello” class:

```
#include <hello.h>
main()
{
SOMClass helloCls; /*  A pointer for the Hello class object */
Hello objA[10];    /*  an array of Hello instances */
unsigned char *buffer;
int i;
int size;

/* create the Hello class object:  */
helloCls = HelloNewClass(Hello_MajorVersion, Hello_MinorVersion);

/* get the amount of space needed for a Hello instance:
 * (somGetInstanceSize is a method provided by SOM.) */
size = _somGetInstanceSize(helloCls);
size = ((size+3)/4)*4;  /* round up to doubleword multiple */

/* allocate the total space needed for ten instances: */
buffer = SOMMalloc(10*size);

/* convert the space into ten separate Hello instances: */
for (i=0; i<10; i++)
   objA[i] = HelloRenew(buffer+i*size);
...
...
/* Uninitialize the objects and free them */
for (i=0; i<10; i++)
  _somUninit(objA[i]);
SOMFree(buffer);
}
```

When an object created with the <*className*>**Renew** macro is no longer needed, its storage must be freed using the dual to whatever method was originally used to allocate the storage. Two method pairs are typical:

- For example, if an object was originally initialized using the <*className*>**New** macro, then, as discussed previously, the client should use the **somFree** method on it.
- On the other hand, if the program uses the **SOMMalloc** function to allocate memory, as illustrated in the example above, then the **SOMFree** function must be called to free the objects' storage (because **SOMFree** is the dual to **SOMMalloc**). Before doing so, however, the objects in the region to be freed should be deinitialized by invoking the **somUninit** method on them. This allows each object to free any memory that it may have allocated without the programmer's knowledge. (The **somFree** method also calls the **somUninit** method.)

For C++ programmers with usage bindings, SOM recognizes the **new** operator, just as in standard C++, using the form:

new <*className*>

For example:

```
obj = new Hello;
```

The **new** operator allocates enough space for an instance of <*className*>, creates a new, initialized class instance, and returns a pointer to it. The **new** operator automatically creates the class object for <*className*>, as well as its ancestor classes and metaclass, if needed.

SOM objects created using the **new** operator should be freed using the **delete** operator, just as for C++ objects:

```
delete obj;
```

When previously allocated space will be used to hold a new object, C++ programmers should use the **somRenew** method, described below. C++ bindings do not provide a macro for this purpose.

somNew and somRenew: C and C++ programmers, as well programmers using other languages, can create instances of a class using the SOM methods **somNew** and **somRenew**, invoked on the class object. As discussed and illustrated above for the C bindings, the class object must first be created using the <*className*>**NewClass** procedure (or, perhaps, using the **somFindClass** method — see the section “Using class objects,” to follow later in this chapter). The **somNew** method invoked on the class object creates a new instance of the class and returns a pointer to it. For instance, the following C example creates a new object of the “Hello” class.

```
#include <hello.h>
main()
{
  SOMClass helloCls;   /* a pointer to the Hello class */
  Hello obj;           /* a pointer to an Hello instance */
  /* create the Hello class  */
  helloCls = HelloNewClass(Hello_MajorVersion, Hello_MinorVersion);
  obj = _somNew(helloCls); /* create the Hello instance */
}
```

An object created using the **somNew** method should be freed by invoking the **somFree** method on it after the client program is finished using the object.

The **somRenew** method invoked on the class object creates a new instance of a class using the given space, rather than allocating new space for the object. The method converts the given space into an instance of the class and returns a pointer to it. The argument to **somRenew** must point to a block of storage large enough to hold the new instance. The method **somGetInstanceSize** can be used to determine the amount of memory required. For example, the following C++ code creates ten instances of the “Hello” class:

```
#include <hello.xh>
#include <somcls.xh>
main()
{
  SOMClass *helloCls; // a pointer to the Hello class
  Hello *objA[10];    //  an array of Hello instance pointers
  unsigned char *buffer;
  int i;
  int size;

// create the Hello class object
helloCls = HelloNewClass(Hello_MajorVersion, Hello_MinorVersion);

// get the amount of space needed for a Hello instance:
size = helloCls->somGetInstanceSize();
size = ((size+3)/4)*4;  // round up to doubleword multiple

// allocate the total space needed for ten instances
buffer = SOMMalloc(10*size);
```

```
// convert the space into ten separate Hello objects
for (i=0; i<10; i++)
   objA[i] = helloCls->somRenew(buffer+i*size);

 ...

// Uninitialize the objects and free them
 for (i=0; i<10; i++)
   objA[i]->somUninit();
 SOMFree(buffer);
}
```

The **somNew** and **somRenew** methods are useful for creating instances of a class when the header file for the class is not included in the client program at compile time. (The name of the class might be specified by user input, for example.) However, the <*className*>**New** macro (for C) and the **new** operator (for C++) can *only* be used for classes whose header file is included in the client program at compile time.

Objects created using the **somRenew** method should be freed by the client program that allocated it, using the dual to whatever allocation approach was initially used. If the method **somFree** is not appropriate (because the method **somNew** was not initially used), then, before memory is freed, the object should be explicitly deinitialized by invoking the **somUninit** method on it. (The **somFree** method calls the **somUninit** method, also.)

Invoking methods on objects

For C programmers with usage bindings: To invoke a method in C, use the macro:

_<*methodName*> (*receiver, args)*

(that is, an underscore followed by the method name). Arguments to the macro are the receiver of the method followed by all of the arguments to the method. For example:

```
_foo(obj, somGetGlobalEnvironment(), x, y)
```

invokes method “foo” on “obj” (the remaining arguments are arguments to the method “foo”). This expression can be used anywhere that a standard function call can be used in C.

In C, calls to methods defined using IDL require at least two arguments — a pointer to the *receiving object* (the object responding to the method) and a value of type (**Environment ***). The **Environment** data structure is specified by CORBA, and is used to pass environmental information between a caller and a called method. For example, it is used to return exceptions. (For more information on how to supply and use the **Environment** structure, see the later section entitled “Exceptions and error handling.”)

In the IDL definition of a method, by contrast, the receiver and the **Environment** pointer are *not* listed as parameters to the method. (Unlike the receiver, the **Environment** pointer is considered a method parameter, even though it is never explicitly specified in IDL. For this reason, it is called an *implicit* method parameter.) For example, if a method is defined in a .idl file with two parameters, as in:

```
int foo (in char c, in float f);
```

then the method would be invoked with four arguments, as in:

```
intvar = _foo(obj, somGetGlobalEnvironment(), x, y);
```

where “obj” is the object responding to the method and “x” and “y” are the arguments corresponding to “c” and “f”, above.

If the IDL specification of the method includes a *context* specification, then the method has an additional (implicit) **context** parameter. Thus, when invoking the method, this argument must follow immediately after the **Environment** pointer argument. (None of the SOM-supplied methods require **context** arguments.) The **Environment** and **context** method parameters are prescribed by the CORBA standard.

If the IDL specification of the class that introduces the method includes the **callstyle=oidl** modifier, then the (**Environment ***) and **context** arguments should not be supplied when invoking the method. That is, the receiver of the method call is followed immediately by the arguments to the method (if any). Some of the classes supplied in the SOMobjects Toolkit (including **SOMObject, SOMClass**, and **SOMClassMgr**) are defined in this way, to ensure compatibility with the previous release of SOM. The *SOMobjects Developer Toolkit: Programmers Reference Manual* specifies for each method whether these arguments are used.

If you use a C expression to compute the first argument to a method call (the receiver), you must use an expression without side effects, because the first argument is evaluated twice by the **_**<*methodName*> macro expansion. In particular, a **somNew** method call or a macro call of <*className*>**New** can *not* be used as the first argument to a C method call, because doing so would create two new class instances rather than one.

If a client program uses the bindings for two different classes that introduce or inherit two different methods of the same name, then the _<*methodName*> macro described above (called the *short form*) will not be provided by the bindings, because the macro would be ambiguous in that circumstance. The following *long form* macro, however, is always provided by the usage bindings for each class that supports the method:

<*className*>_<*methodName*> (*receiver, args*)

For example, method "foo" supported by class "Bar" can be invoked as:

```
Bar_foo(obj, somGetGlobalEnvironment(), x, y)       (in C)
```

where "obj" has type "Bar" and "x" and "y" are the arguments to method "foo". A programmer will usually know what type an object is expected to have. If this is not known, but the different methods have the same signature, the method can be invoked using name-lookup resolution, as described in the next section.

As a convenience, methods whose final argument is a **va_list**, such as:

```
void setMany(in short start, in short numArgs, in va_list ap);
```

can be invoked by specifying a variable number of arguments, as in:

```
_setMany(aVector, somGetGlobalEnvironment(), 2, 4, 20, 12, 32, 41);
```

This is the short form of the invocation macro. Thus, the variable-arguments form illustrated above is only available in the absence of ambiguity. Alternatively, the long-form macro (which is always available) requires a **va_list**, as suggested by the method definition. Thus, to use a **va_list** argument, the method must be invoked as <*className*>_<*methodName*>, where <*className*> is the name of a class that supports the method.

For example, assuming that class "Vector" supports the "setMany" method above, the following C code constructs a variable of type **va_list** containing the arguments to "setMany" and invokes the "setMany" method with this variable:

```
va_list start_ap, ap;
Vector aVector = VectorNew();
...
start_ap = ap = (char *) SOMMalloc(4 * sizeof(long));
va_arg(ap, long) = 20;
va_arg(ap, long) = 12;
va_arg(ap, long) = 32;
va_arg(ap, long) = 41;
Vector_setMany(aVector, somGetGlobalEnvironment(), 2, 4, start_ap);
```

Note: In most cases, a C programmer may use either the short or the long form of a method invocation macro interchangeably. However, *only* the long form complies with the CORBA standard for C usage bindings. If you wish to write code that can be easily ported to other vendor platforms that support the CORBA standard, use the long form exclusively. The long form is always available for every method that a class supports. The short form is provided both as a programming convenience and for source code compatibility with release 1 of SOM.

For C++ programmers with usage bindings: To invoke a method, use the standard C++ form shown below:

obj–><*methodName*> (*args*)

where *args* are the arguments to the method.

For instance, the following example invokes method "foo" on "obj":

```
obj->foo(somGetGlobalEnvironment(), x, y)
```

All methods introduced by classes declared using IDL (except those having the SOM IDL **callstyle=oidl** modifier) have at least one parameter — a value of type (**Environment ***). The **Environment** data structure is used to pass environmental information between a caller and a called method. For example, it is used to return exceptions. For more information on how to supply and use the **Environment** structure, see the later section entitled "Exceptions and error handling."

The **Environment** pointer is an implicit parameter; in the IDL definition of a method, the **Environment** pointer is *not* explicitly listed as a parameter to the method. For example, if a method is defined in IDL with two explicit parameters, as in:

```
int foo (in char c, in float f);
```

then the method would be invoked from C++ bindings with three arguments, as in:

```
intvar = obj->foo(somGetGlobalEnvironment(), x, y);
```

where "obj" is the object responding to the method and "x" and "y" are the arguments corresponding to "c" and "f", above.

If the IDL specification of the method includes a *context* specification, then the method has a second implicit parameter, of type **context**, and the method must be invoked with an additional **context** argument. This argument must follow immediately after the **Environment** pointer argument. (No SOM-supplied methods require **context** arguments.) The **Environment** and **context** method parameters are prescribed by the CORBA standard.

If the IDL specification of the class that introduces the method includes the **callstyle=oidl** modifier, then the (**Environment ***) and **context** arguments should not be supplied when the method is invoked. Some of the classes supplied in the SOMobjects Toolkit (including **SOMObject, SOMClass**, and **SOMClassMgr**) are defined in this way, to ensure compatibility with the previous release of SOM. The *SOMobjects Developer Toolkit: Programmers Reference Manual* specifies for each method whether these arguments are used.

As a convenience, methods whose final argument is a **va_list**, such as:

```
void setMany(in short start, in short numArgs, in va_list ap);
```

can be invoked either by specifying a variable number of arguments, as in:

```
aVector->setMany(somGetGlobalEnvironment(), 2, 4, 20, 12, 32, 41);
```

or by specifying a **va_list** in place of the variable number of arguments. To invoke a method using a **va_list** argument, the method must be invoked as <*className*>_<*methodName*>, where <*className*> is the name of the class that introduces the method. For example, assuming that class “Vector” defines the “setMany” method above, the following C++ code constructs a variable of type **va_list** containing the arguments to “setMany” and invokes the “setMany” method with this variable as an argument:

```
va_list start_ap, ap;
Vector *aVector = new Vector;
...
start_ap = ap = (char *) SOMMalloc(4*sizeof(long));
va_arg(ap, long) = 20;
va_arg(ap, long) = 12;
va_arg(ap, long) = 32;
va_arg(ap, long) = 41;
aVector->Vector_setMany(somGetGlobalEnvironment(), 2, 4, start_ap);
```

For non-C/C++ programmers: To invoke a *static method* (that is, a method declared when defining an OIDL or IDL object interface) without using the C or C++ usage bindings, a programmer can use the **somResolve** procedure. The **somResolve** procedure takes as arguments a pointer to the object on which the method is to be invoked and a *method token* for the desired method. It returns a pointer to the method’s procedure (or raises a fatal error if the object does not support the method). Depending on the language and system, it may be necessary to cast this procedure pointer to the appropriate type; the way this is done is language-specific.

The method is then invoked by calling the procedure returned by **somResolve** (the means for calling a procedure, given a pointer to it, is language-specific), passing the method’s receiver, the **Environment** pointer (if necessary), the **context** argument (if necessary) and the remainder of the method’s arguments, if any. (See the section above for C programmers; the arguments to a method procedure are the same as the arguments passed using the long form of the C-language method-invocation macro for that method.)

Using **somResolve** requires the programmer to know where to find the *method token* for the desired method. Method tokens are available from class objects that support the method (via the method **somGetMethodToken**), or from a global data structure, called the *ClassData structure,* corresponding to the class that introduces the method. In C and C++ programs with access to the definitions for ClassData structures provided by usage bindings, the method token for method *methodName* introduced by class *className* may be accessed by the following expression:

<*className*>ClassData.<*methodName*>

For example, the method token for method “sayHello” introduced by class “Hello” is stored at location `HelloClassData.sayHello`, for C and C++ programmers. The way method tokens are accessed in other languages is language-specific.

As an example of using offset resolution to invoke methods from a programming language other than C/C++, one would do the following to create an instance of a SOM Class *X* in Smalltalk:

1. Initialize the SOM run-time environment, if it has not previously been initialized, using the **somEnvironmentNew** function.
2. If the class object for class *X* has not yet been created, use **somResolve** with arguments **SOMClassMgrObject** (returned by **somEnvironmentNew** in step 1) and the method token for the **somFindClass** method, to obtain a method procedure pointer for the **somFindClass** method. Use the method procedure for **somFindClass** to create the class object for class *X*: Call the procedure with arguments **SOMClassMgrObject**, the result of calling the **somIdFromString** function with argument *“X”,* and the major and minor version numbers for class *X* (or zero). The procedure returns the class object for class *X*.

3. Use **somResolve** with arguments representing the class object for *X* (returned by **somFindClass** in step 2) and the method token for the **somNew** method, to obtain a method procedure pointer for method **somNew.** (The **somNew** method is used to create instances of class *X*.)
4. Call the method procedure for **somNew** (using the method procedure pointer obtained in step 3) with the class object for *X* (returned by **somFindClass** in step 3) as the argument. The procedure returns a new instance of class *X*.

In addition to **somResolve**, SOM also supplies the **somClassResolve** procedure. Instead of an object, the **somClassResolve** procedure takes a class as its first argument, and then selects a method procedure from the instance method table of the passed class. (The **somResolve** procedure, by contrast, selects a method procedure from the instance method table of the class of which the passed object is an instance.) The **somClassResolve** procedure therefore supports *casted* method resolution. See the *SOMobjects Developer Toolkit: Programmers Reference Manual* for more information on **somResolve** and **somClassResolve**.

If the programmer does not know at compile time which class introduces the method to be invoked, or if the programmer cannot directly access method tokens, then the procedure **somResolveByName** can be used to obtain a method procedure using name-lookup resolution, as described in the next section.

If the signature of the method to be invoked is not known at compile time, but can be discovered at run time, use **somResolve** or **somResolveByName** to get a pointer to the **somDispatch** method procedure, then use it to invoke the specific method, as described below under "Method name or signature not known at compile time."

Using name-lookup method resolution

<u>For C/C++ programmers</u>: Offset resolution is the most efficient way to select the method procedure appropriate to a given method call. Client programs can, however, invoke a method using "name-lookup" resolution instead of offset resolution. The C and C++ bindings for method invocation use offset resolution by default, but methods defined with the **namelookup** SOM IDL modifier result in C bindings in which the short form invocation macro uses name-lookup resolution instead. Also, for both C and C++ bindings, a special *lookup_<methodName>* macro is defined.

Name-lookup resolution is appropriate in the case where a programmer <u>knows at compile time which arguments</u> will be expected by a method (that is, its *signature*), but <u>does not know the *type* of the object</u> on which the method will be invoked. For example, name-lookup resolution can be used when two different classes introduce <u>different methods of the same name and signature</u>, and it is not known which method should be invoked (because the type of the object is not known at compile time).

Name-lookup resolution is also used to invoke *dynamic methods* (that is, methods that have been added to a class's interface at run time rather than being specified in the class's IDL specification). For more information on name-lookup method resolution, see the topic "Method Resolution" in Chapter 4, "Implementing SOM Classes."

<u>For C</u>: To invoke a method using name-lookup resolution, <u>when using the C bindings for a method that has been implemented with the **namelookup** modifier</u>, use either of the following macros:

_*<methodName>* (*receiver, args)*

lookup_*<methodName>* (*receiver, args)*

Thus, the short-form method invocation macro results in name-lookup resolution (rather than offset resolution), when the method has been defined as a **namelookup** method. (The long form of the macro for offset resolution is still available in the C usage bindings.) If the method takes a variable number of arguments, then the first form shown above is used when supplying a variable number of arguments, and the second form is used when supplying a **va_list** argument in place of the variable number of arguments.

For C++: To invoke a method using name-lookup resolution, when using the C++ bindings for a method that has been defined with the **namelookup** modifier, use either of the following macros:

lookup_<*methodName*> (*receiver, args)*

<className>**_lookup_**<*methodName*> (*receiver, args)*

If the method takes a variable number of arguments, then the first form shown above is used when supplying a variable number of arguments, and the second form is used when supplying a **va_list** argument in place of the variable number of arguments. Note that the offset-resolution forms for invoking methods using the C++ bindings are also still available, even if the method has been defined as a **namelookup** method.

For C/C++: To invoke a method using name-lookup resolution, when the method has *not* been defined as a **namelookup** method:

- Use the **somResolveByName** procedure (described in the following section)**,** or any of the methods **somLookupMethod, somFindMethod** or **somFindMethodOk** to obtain a pointer to the procedure that implements the desired method.
- Then, invoke the desired method by calling that procedure, passing the method's intended receiver, the **Environment** pointer (if needed), the **context** argument (if needed), and the remainder of the method's arguments, if any.

The **somLookupMethod, somFindMethod** and **somFindMethodOK** methods are invoked on a class object (the class of the method receiver should be used), and take as an argument the **somId** for the desired method (which can be obtained from the method's name using the **somIdFromString** function). For more information on these methods, see the *SOMobjects Developer Toolkit: Programmers Reference Manual.*

Important Note: SOM provides many ways for a SOM user to acquire a pointer to a method procedure. Once this is done, it becomes the user's responsibility to make appropriate use of this procedure.

- First, the procedure should only be used on objects for which this is appropriate — otherwise, run-time errors are likely to result.
- Second, when the procedure is used, it is essential that the compiler be given correct information concerning the signature of the method and the linkage required by the method. (On many systems, there are different ways to pass method arguments, and linkage information tells a compiler how to pass the arguments indicated by a method's signature).

SOM method procedures on OS/2 must be called with "system" linkage. On AIX, there is only one linkage convention for procedure calls. While C and C++ provide standard ways to indicate a method signature, the way to indicate linkage information depends on the specific compiler and system. For each method declared using OIDL or IDL, the C and C++ usage bindings therefore use conditional macros and a typedef to name a type that has the correct linkage convention. This type name can then be used by programmers with access to the usage bindings for the class that introduces the method whose procedure pointer is used. The type is named **somTD_**<*className*>_<*methodName*>. This is illustrated in the following example, and further details are provided in the section below, titled, "Obtaining a method's procedure pointer."

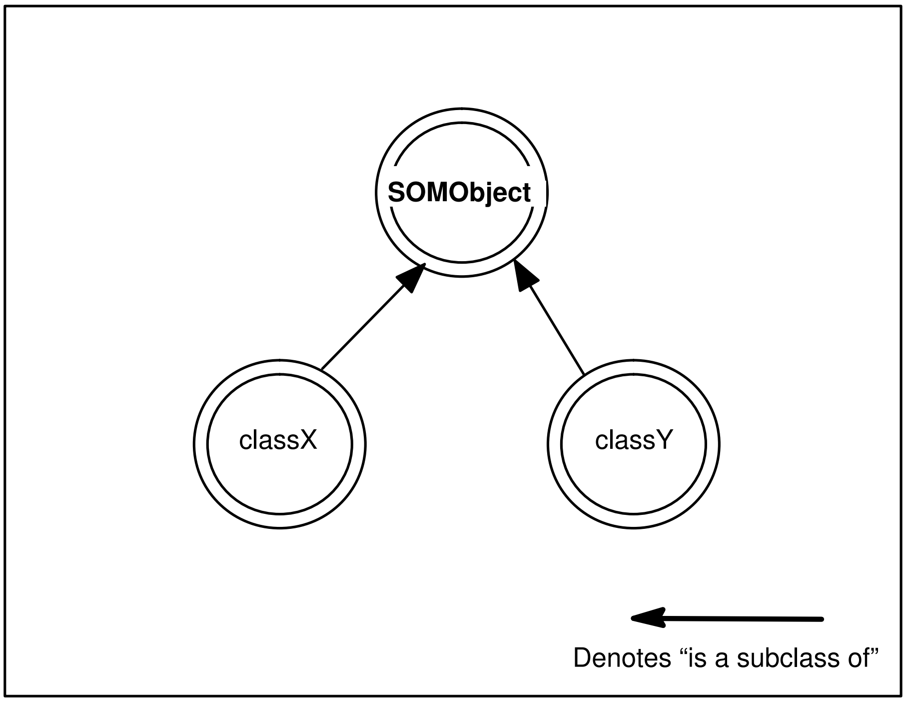
A name-lookup example

The following example shows the use of name-lookup by a SOM client programmer. Name-lookup resolution is appropriate when a programmer knows that an object will respond to a method of some given name, but does not know enough about the type of the object to use offset method resolution. How can this happen? It normally happens when a programmer wants to write generic code, using methods of the same name and signature that are applicable to different classes of objects, and yet these classes have no common ancestor that introduces the method. This can easily occur in single-inheritance systems (such as Smalltalk and SOM release 1) and can also happen in multiple-inheritance systems such as SOM release 2 — when class hierarchies designed by different people are brought together for clients' use.

If multiple inheritance is available, it is always possible to create a common class ancestor into which methods of this kind can be migrated. A refactoring of this kind often implements a semantically pleasing generalization that unifies common features of two previously unrelated class hierarchies. This step is most practical, however, when it does not require the redefinition or recompilation of current applications that use offset resolution. SOM is unique in that it allows this.

However, such refactoring must redefine the classes that originally introduced the common methods (so the methods can be inherited from the new "unifying" class instead). A client programmer who simply wants to create an application may not control the implementations of the classes. Thus, the use of name-lookup method resolution seems the best alternative for programmers who do not want to define new classes, but simply to make use of available ones.

For example, assume the existence of two different SOM classes, "classX" and "classY", whose only common ancestor is **SOMObject**, and who both introduce a method named "reduce" that accepts a *string* as an argument and returns a *long*. We assume that the classes were not designed in conjunction with each other. As a result, it is unlikely that the "reduce" method was defined with a **namelookup** modifier. The following figure illustrates the class hierarchy for this example.



Following is a C++ generic procedure that uses name-lookup method resolution to invoke the "reduce" method on its argument, which may be either of type "classX" or "classY". Note that there is no reason to include classY's usage bindings, since the typedef provided for the "reduce" method procedure in "classX" is sufficient for invoking the method procedure, independently of whether the target object is of type "classX" or "classY".

```
#include <classX.xh> // use classX's method proc typedef

// this procedure can be invoked on a target of type
// classX or classY.

long generic_reduce1(SOMObject *target, string arg)
{
   somTD_classX_reduce reduceProc = (somTD_classX_reduce)
        somResolveByName(target, "reduce");
   return reduceProc(target, arg);
}
```

On the other hand, If the classes were designed in conjunction with each other, and the class designer felt that programmers might want to write generic code appropriate to either class of object, the **namelookup** modifier might have been used. This is a possibility in SOM release 2, even with multiple inheritance, but it is much more likely that the class designer would use multiple inheritance to introduce the reduce method in a sepatate class, and then use this other class as a parent for both classX and classY (thereby allowing the use of offset resolution).

In any case, if the "reduce" method in "classX" were defined as a **namelookup** method, the following code would be appropriate. Note that the name-lookup support provided by "classX" usage bindings is still appropriate for use on targets that do not have type "classX". As a result, the "reduce" method introduced by "classY" need not have been defined as a **namelookup** method.

```
#include <classX.xh> // use classX's name-lookup support

// this procedure can be invoked on a target of type
// classX or classY.

long generic_reduce2(SOMObject *target, string arg)
{
   return lookup_reduce(target, arg);
}
```

For non-C/C++ programmers: Name-lookup resolution is useful for non-C/C++ programmers when the type of an object on which a method must be invoked is not known at compile time or when method tokens cannot be directly accessed by the programmer. To invoke a method using name-lookup resolution when not using the C or C++ usage bindings, use the **somResolveByName** procedure to acquire a procedure pointer. How the programmer indicates the method arguments and the linkage convention in this case is compiler specific.

The **somResolveByName** procedure takes as arguments a pointer to the object on which the method is to be invoked and the name of the method, as a string. It returns a pointer to the method's procedure (or NULL if the method is not supported by the object). The method can then be invoked by calling the method procedure, passing the method's receiver, the **Environment** pointer (if necessary), the **context** argument (if necessary), and the rest of the method's arguments, if any. (See the section above for C programmers; the arguments to a method procedure are the same as the arguments passed to the long-form C-language method-invocation macro for that method.)

As an example of invoking methods using name-lookup resolution using the procedure **somResolveByName**, the following steps are used to create an instance of a SOM Class *X* in Smalltalk:

1. Initialize the SOM run-time environment (if it is not already initialized) using the **somEnvironmentNew** function.
2. If the class object for class *X* has not yet been created, use **somResolveByName** with the arguments **SOMClassMgrObject** (returned by **somEnvironmentNew** in

step 1) and the string *"somFindClass",* to obtain a method procedure pointer for the **somFindClass** method. Use the method procedure for **somFindClass** to create the class object for class *X*: Call the method procedure with these four arguments: **SOMClassMgrObject**; the variable holding class *X*'s **somId** (the result of calling the **somIdFromString** function with argument *"X"*); and the major and minor version numbers for class *X* (or zero). The result is the class object for class *X*.

3. Use **somResolveByName** with arguments the class object for *X* (returned by **somFindClass** in step 2) and the string *"somNew"*, to obtain a method procedure pointer for method **somNew.** (This **somNew** method is used to create instances of a class.)
4. Call the method procedure for **somNew** (using the method procedure pointer obtained in step 3) with the class object for *X* (returned by **somFindClass** in step 3) as the argument. The result is a new instance of class *X*. How the programmer indicates the method arguments and the linkage convention is compiler-specific.

Obtaining a method's procedure pointer

Method resolution is the process of obtaining a pointer to the procedure that implements a particular method for a particular object at run time. The method is then invoked subsequently by calling that procedure, passing the method's intended receiver, the **Environment** pointer (if needed), the **context** argument (if needed), and the method's other arguments, if any. C and C++ programmers may wish to obtain a pointer to a method's procedure for efficient repeated invocations.

Obtaining a pointer to a method's procedure is achieved in one of two ways, depending on whether the method is to be resolved using **offset** resolution or **name-lookup** resolution. Obtaining a method's procedure pointer via offset resolution is faster, but it requires that the name of the class that introduces the method and the name of the method be known at compile time. It also requires that the method be defined as part of that class's interface in the IDL specification of the class. (See the topic "Method Resolution" in Chapter 4, "Implementing SOM Classes," for more information on offset and name-lookup method resolution.)

Offset resolution

To obtain a pointer to a procedure using **offset** resolution, the C/C++ usage bindings provide the **SOM_Resolve** and **SOM_ResolveNoCheck** macros. The usage bindings themselves use the first of these, **SOM_Resolve**, for offset-resolution method calls. The difference in the two macros is that the **SOM_Resolve** macro performs consistency checking on its arguments, but the macro **SOM_ResolveNoCheck**, which is faster, does not. Both macros require the same arguments:

SOM_Resolve(<*receiver*>, <*className*>, <*methodName*>)
SOM_ResolveNoCheck(<*receiver*>, <*className*>, <*methodName*>)

where the arguments are as follows:

receiver — The object to which the method will apply. It should be specified as an expression without side effects.

className — The name of the class that introduces the method.

methodName — The name of the desired method.

These two names (*className* and *methodName*) must be given as tokens, rather than strings or expressions. (For example, as Animal rather than "Animal".) If the symbol **SOM_TestOn** is defined and the symbol **SOM_NoTest** is not defined in the current compilation unit, then **SOM_Resolve** verifies that *receiver* is an instance of *className* or some class derived from *className*. If this test fails, an error message is output and execution is terminated.

The **SOM_Resolve** and **SOM_ResolveNoCheck** macros use the procedure **somResolve** to obtain the entry-point address of the desired method procedure (or raise a fatal error if *methodName* is not introduced by *className).* This result can be directly applied to the method arguments, or stored in a variable of generic procedure type (for example, **somMethodPtr**) and retained for later method use. This second possibility would result in a loss of information, however, for the reasons now given.

The **SOM_Resolve** or **SOM_ResolveNoCheck** macros are especially useful because they cast the method procedure they obtain to the right type to allow the C or C++ compiler to call this procedure with *system linkage* and with the appropriate arguments. This is why the result of **SOM_Resolve** is immediately useful for calling the method procedure, and why storing the result of **SOM_Resolve** in a variable of some "generic" procedure type results in a loss of information. The correct type information can be regained, however, because the type used by **SOM_Resolve** for casting the result of **somResolve** is available from C/C++ usage bindings using the typedef name **somTD_**<*className*>_<*methodName*>. This type name describes a pointer to a method procedure for *methodName* introduced by class *className*. If the final argument of the method is a **va_list**, then the method procedure returned by **SOM_Resolve** or **SOM_ResolveNoCheck** must be called with a **va_list** argument, and not a variable number of arguments.

Below is a C example of using **SOM_Resolve** to obtain a method procedure pointer for method "sayHello", introduced by class "Hello", and using it to invoke the method on "obj." (Assume that the only argument required by the "sayHello" method is the **Environment** pointer.)

```
somMethodProc *p;
SOMObject obj = HelloNew();
p = SOM_Resolve(obj, Hello, sayHello);
((somTD_Hello_sayHello)p) (obj, somGetGlobalEnvironment());
```

SOM_Resolve and **SOM_ResolveNoCheck** can only be used to obtain method procedures for *static methods* (methods that have been declared in an IDL specification for a class) and not methods that are added to a class at run time. See the *SOMobjects Programmers Reference Manual* for more information and examples on **SOM_Resolve** and **SOM_ResolveNoCheck**.

Name-lookup method resolution

To obtain a pointer to a method's procedure using **name-lookup** resolution, use the **somResolveByName** procedure (described in the following section)**,** or any of the **somLookupMethod, somFindMethod** and **somFindMethodOK** methods. These methods are invoked on a class object that supports the desired method, and they take an argument specifying the a **somId** for the desired method (which can be obtained from the method's name using the **somIdFromString** function). For more information on these methods and for examples of their use, see the *SOMobjects Developer Toolkit: Programmers Reference Manual*.

Method name or signature not known at compile time

If the programmer does not know a method's name at compile time (for example, it might be specified by user input), then the method can be invoked in one of two ways, depending upon whether its signature is known:

- Suppose the <u>signature of the method is known</u> at compile time (even though the method name is not). In that case, when the name of the method becomes available at run time, the **somLookupMethod, somFindMethod** or **somFindMethodOk** methods or the **somResolveByName** procedure can be used to <u>obtain a pointer to the method's procedure</u> using name-lookup method resolution, as described in the preceding topics. That method procedure can then be invoked, passing the method's intended receiver, the **Environment** pointer (if needed), the **context** argument (if needed), and the remainder of the method's arguments.
- If the method's signature is unknown until run time, then dispatch-function resolution is indicated, as described in the next topic.

Dispatch-function method resolution

If the *signature* of the method is *not* known at compile time (and hence the method's argument list cannot be constructed until run time), then the method can be invoked at run time by (a) placing the arguments in a variable of type **va_list** at run time and (b) either using the **somGetMethodData** method followed by use of the **somApply** function, or by invoking the **somDispatch** or **somClassDispatch** method. Using **somApply** is more efficient, since this is what the **somDispatch** method does, but it requires two steps instead of one. In either case, the result invokes a "stub" procedure called an *apply stub*, whose purpose is to remove the method arguments from the **va_list**, and then pass them to the appropriate method procedure in the way expected by that procedure. For more information on these methods and for examples of their use, see the **somApply** function, and the **somGetMethodData, somDispatch,** and **somClassDispatch** methods in the *SOMobjects Programmers Reference Manual*.

Accessing Attributes

In addition to methods, SOM objects can also have attributes. An *attribute* is an IDL shorthand for declaring methods, and does not necessarily indicate the presence of any particular instance data in an object of that type. Attribute methods are called "get" and "set" methods. For example, if a class "Hello" declares an attribute called "msg", then object variables of type "Hello" will support the methods **_get_msg** and **_set_msg** to access or set the value of the "msg" attribute. (Attributes that are declared as "readonly" have no "set" method, however.)

The "get" and "set" methods are invoked in the same way as other methods. For example, given class "Hello" with attribute "msg" of type **string**, the following code segments set and get the value of the "msg" attribute:

For C:

```
#include <hello.h>
Hello obj;
Environment *ev = somGetGlobalEnvironment();

obj = HelloNew();
__set_msg(obj, ev, "Good Morning");/*note:two leading underscores */
printf("%s\n", __get_msg(obj, ev));
```

For C++:

```
#include <hello.xh>
#include <stdio.h>
Hello *obj;
Environment *ev = somGetGlobalEnvironment();

obj = new Hello;
obj->_set_msg(ev, "Good Morning");
printf("%s\n", obj->_get_msg(ev));
```

Using class objects

Using a class object encompasses three aspects: getting the class of an object, creating a new class object, or simply referring to a class object through the use of a pointer.

Getting the class of an object

To get the class that an object is an instance of, SOM provides a method called **somGetClass**. The **somGetClass** method takes an object as its only argument and returns a pointer to the class object of which it is an instance. For example, the following statements store in "myClass" the class object of which "obj" is an instance.

```
myClass = _somGetClass(obj);    (for C)
myClass = obj->somGetClass();   (for C++)
```

Getting the class of an object is useful for obtaining information about the object; in some cases, such information cannot be obtained directly from the object, but only from its class. The section below entitled "Getting information about a class" describes the methods that can be invoked on a class object after it is obtained using **somGetClass**.

The **somGetClass** method can be overridden by a class to provide enhanced or alternative semantics for its objects. Because it is usually important to respect the intended semantics of a class of objects, the **somGetClass** method should normally be used to access the class of an object.

In a few special cases, it is not possible to make a method call on an object in order to determine its class (for example, see "Customizing method resolution" in Chapter 5, "SOM Customization Features"). For such situations, SOM provides the **SOM_GetClass** macro. In general, the **somGetClass** method and the **SOM_GetClass** macro may have different behavior (if **somGetClass** has been overridden). This difference may be limited to side effects, but it is possible for their results to differ as well. The **SOM_GetClass** macro should only be used when absolutely necessary.

Creating a class object

A class object is created automatically the first time the <*className*>**New** macro (for C) or the **new** operator (C++) is invoked to create an instance of that class. In other situations, however, it may be necessary to create a class object explicitly, as this section describes.

Using <*className*>Renew or somRenew

It is sometimes necessary to create a class object before creating any instances of the class. For example, creating instances using the <*className*>**Renew** macro or the **somRenew** method requires knowing how large the created instance will be, so that memory can be allocated for it. Getting this information requires creating the class object (see the example under "Creating instances of a class" early in this chapter). As another example, a class object must be explicitly created when a program does not use the SOM bindings for a class. Without SOM bindings for a class, its instances must be created using **somNew** or **somRenew**, and these methods require that the class object be created in advance.

Use the <*className*>**NewClass** procedure to create a class object :

- When using the C/C++ language bindings for the class, and
- When the name of the class is known at compile time.

Using <*className*>NewClass

The <*className*>**NewClass** procedure initializes the SOM run-time environment, if necessary, creates the class object (unless it already exists), creates class objects for the ancestor classes and metaclass of the class, if necessary, and returns a pointer to the newly created class object. After its creation, the class object can be referenced in client code using the macro

_<*className*>	(for C and C++ programs)

or the expression

<*className*>**ClassData.classObject**	(for C and C++ programs).

The <*className*>**NewClass** procedure takes two arguments, the major version number and minor version number of the class. These numbers are checked against the version numbers built into the class library to determine if the class is compatible with the client's expectations. The class is compatible if it has the same major version number and the same or a higher minor version number. If the class is not compatible, an error is raised. Major version numbers usually only change when a significant enhancement or incompatible change is made to a class. Minor version numbers change when minor enhancements or fixes are made. Downward compatibility is usually maintained across changes in the minor version number. Zero can be used in place of version numbers to bypass version number checking.

When using SOM bindings for a class, these bindings define constants representing the major and minor version numbers of the class at the time the bindings were generated. These constants are named <*className*>_MajorVersion and <*className*>_MinorVersion. For example, the following procedure call:

```
AnimalNewClass(Animal_MajorVersion, Animal_MinorVersion);
```

creates the class object for class "Animal". Thereafter, `_Animal` can be used to reference the "Animal" class object.

The preceding technique for checking version numbers is not failsafe. For performance reasons, the version numbers for a class are only checked when the class object is created, and not when the class object or its instances are used. Thus, run-time errors may result when usage bindings for a particular version of a class are used to invoke methods on objects created by an earlier version of the class.

Using somFindClass or somFindClsInFile

To create a class object when *not* using the C/C++ language bindings for the class, or when the class name is *not* known at compile time:

- First, initialize the SOM run-time environment by calling the **somEnvironmentNew** function (unless it is known that the SOM run-time environment has already been initialized).
- Then, use the **somFindClass** or **somFindClsInFile** method to create the class object. (The class must already be defined in a dynamically linked library, or DLL.)

The **somEnvironmentNew** function initializes the SOM run-time environment. That is, it creates the four primitive SOM objects (**SOMClass, SOMObject, SOMClassMgr,** and the **SOMClassMgrObject**), and it initializes SOM global variables. The function takes no arguments and returns a pointer to the **SOMClassMgrObject**.

Note: Although **somEnvironmentNew** must be called before using other SOM functions and methods, explicitly calling **somEnvironmentNew** is usually not necessary when using the C/C++ bindings, because the macros for <*className*>**NewClass**, <*className*>**New**, and <*className*>**Renew** call it automatically, as does the **new** operator for C++. Calling **somEnvironmentNew** repeatedly does no harm.

After the SOM run-time environment has been initialized, the methods **somFindClass** and **somFindClsInFile** can be used to create a class object. These methods must be invoked on the class manager, which is pointed to by the global variable **SOMClassMgrObject.** (It is also returned as the result of **somEnvironmentNew**.)

The **somFindClass** method takes the following arguments:

classId	—	A **somId** identifying the name of the class to be created. The **somIdFromString** function returns a *classId* given the name of the class.
major version number	—	The expected major version number of the class.
minor version number	—	The expected minor version number of the class.

The version numbers are checked against the version numbers built into the class library to determine if the class is compatible with the client's expectations.

The **somFindClass** method dynamically loads the DLL containing the class's implementation, if needed, creates the class object (unless it already exists) by invoking its

<*className*>**NewClass** procedure, and returns a pointer to it. If the class could not be created, **somFindClass** returns NULL. For example, the following C code fragment creates the class "Hello" and stores a pointer to it in "myClass":

```
SOMClassMgr cm = somEnvironmentNew();
somId classId = somIdFromString("Hello");
SOMClass myClass = _somFindClass(SOMClassMgrObject, classId,
                       Hello_MajorVersion, Hello_MinorVersion);
. . .
SOMFree(classId);
```

The **somFindClass** method uses **somLocateClassFile** to get the name of the library file containing the class. If the class was defined with a "dllname" class modifier, then **somLocateClassFile** returns that file name; otherwise, it assumes that the class name is the name of the library file. The **somFindClsInFile** method is similar to **somFindClass,** except that it takes an additional (final) argument — the name of the library file containing the class. The **somFindClsInFile** method is useful when a class is packaged in a DLL along with other classes and the "dllname" class modifier has not been given in the class's IDL specification.

Warning: On AIX and Windows, the **somFindClass** and **somFindClsInFile** methods should *not* be used to create a class whose implementation is statically linked with the client program. Instead, the class object should be created using the <*className*>**NewClass** procedure provided by the class's .h/.xh header file. Static linkage is not created by simply including usage bindings in a program, but is implied by use of the offset-resolution invocation macros.

Referring to class objects

Saving a pointer as the class object is created: The <*className*>**NewClass** macro and the **somFindClass** method, used to create class objects, both return a pointer to the newly created class object. Hence, one way to obtain a pointer to a class object is to save the value returned by <*className*>**NewClass** or **somFindClass** when the class object is created.

Getting a pointer after the class object is created: After a class object has been created, client programs can also get a pointer to the class object from the class name. When the class name is known at compile time and the client program is using the C or C++ language bindings, the macro

_<*className*>

can be used to refer to the class object for <*className*>. Also, when the class name is known at compile time and the client program is using the C or C++ language bindings, the expression

<*className*>**ClassData.classObject**

refers to the class object for <*className*>. For example, `_Hello` refers to the class object for class "Hello" in C or C++ programs, and `HelloClassData.classObject` refers to the class object for class "Hello." in C or C++ programs.

Getting a pointer to the class object from an instance: If any instances of the class are known to exist, a pointer to the class object can also be obtained by invoking the **somGetClass** method on such an instance. (See "Getting the class of an object," above.)

Getting a pointer in other situations: If the class name is *not* known until run time, or if the client program is *not* using the C or C++ language bindings, and *no* instances of the class are known to exist, then the **somClassFromId** method can be used to obtain a pointer to a class object after the class object has been created. The **somClassFromId** method should be invoked on the class manager, which is pointed to by the global variable **SOMClassMgrObject.** The only argument to the method is a **somId** for the class name, which can be obtained using the **somIdFromString** function. The method **somClassFromId** returns a pointer to the class object of the specified class. For example, the following C code:

```
SOMClassMgr cm = somEnvironmentNew();
somId classId = somIdFromString("Hello");
SOMClass myClass = _somClassFromId(SOMClassMgrObject,classId,
                        Hello_MajorVersion, Hello_MinorVersion);
SOMFree(classId);
```

stores in "myClass" a pointer to the class object for class "Hello" (or NULL, if the class cannot be created).

Compiling and linking

This section describes how to compile and link C and C++ client programs. Compiling and linking a client program with a SOM class is done in one of two ways, depending on how the class is packaged.

If the class is not packaged as a library (that is, the client program has the implementation source code for the class, as in the examples given in the SOM IDL tutorial), then the client program can be compiled together with the class implementation file as follows. (This assumes that the client program and the class are both implemented in the same language, C or C++. If this is not the case, then each module must be compiled separately to produce an object file and the resulting object files linked together to form an executable.) In the examples below, the environment variable **SOMBASE** refers to the directory in which SOM has been installed. For client program "main" and class "Hello":

Under AIX, for **C** programmers:

```
> xlc -I. -I$SOMBASE/include main.c hello.c -L$SOMBASE/lib -lsomtk \
      -o main
```

Under AIX, for **C++** programmers:

```
> xlC -I. -I$SOMBASE/include main.C hello.C -L$SOMBASE/lib -lsomtk \
      -o main
```

Under OS/2, for **C** programmers:

```
> set LIB=%SOMBASE%\lib;%LIB%
> icc -I. -I%SOMBASE%\include main.c hello.c somtk.lib
```

Under OS/2, for **C++** programmers:

```
> set LIB=%SOMBASE%\lib;%LIB%
> icc -I. -I%SOMBASE%\include main.cpp hello.cpp somtk.lib
```

If the class is packaged as a class library, then the client program, "main", is compiled as above, except that the class implementation file is not part of the compilation. Instead, the "import library" provided with the class library is used to resolve the symbolic references that appear in "main". For example, to compile the C client program "main.c" that uses class "Hello":

Under AIX:

```
> xlc -I. -I$SOMBASE/include main.c -lc -L$SOMBASE/lib -lsomtk \
      -lhello -o main
```

Under OS/2:

```
> set LIB=%SOMBASE%\lib;%LIB%
> icc -I. -I%SOMBASE%\include main.c somtk.lib hello.lib
```

Both of these examples assume that the header files and the import library for the "Hello" class reside in the "include" and "lib" directories where SOM has been installed. If this is not the case, additional path information should be supplied for these files.

3.3 Language-neutral Methods and Functions

This section describes methods, functions, and macros that client programs can use regardless of the programming language in which they are written. In other words, these macros and functions are not part of the C or C++ bindings.

Generating output

The following functions and methods are used to generate output, including descriptions of SOM objects. They all produce their output using the character-output procedure held by the global variable **SOMOutCharRoutine**. The default procedure for character output simply writes the character to *stdout*, but it can be replaced to change the output destination of the methods and functions below. (See Chapter 5 for more information on customizing SOM.)

somDumpSelf — (method) Writes a detailed description of an object, including its class, its location, and its instance data. The receiver of the method is the object to be dumped. An additional argument is the "nesting level" for the description. [All lines in the description will be indented by (2 * level) spaces.]

somPrintSelf — (method) Writes a brief description of an object, including its class and location in memory. The receiver of the method is the object to be printed.

somPrintf — (function) SOM's version of the C "printf" function. It generates character stream output via **SOMOutCharRoutine**. It has the same interface as the C "printf" function.

somVprintf — (function) Represents the "vprint" form of **somPrintf**. Its arguments are a formatting string and a **va_list** holding the remaining arguments.

somPrefixLevel — (function) Generates (via **somPrintf**) spaces to prefix a line at the indicated level. The return type is **void**. The argument is an integer specifying the level. The number of spaces generated is (2 * level).

somLPrintf — (function) Combines **somPrefixLevel** and **somPrintf.** The first argument is the level of the description (as for **somPrefixLevel**) and the remaining arguments are as for **somPrintf** (or for the C "printf" function).

See the *SOMobjects Developer Toolkit: Programmers Reference Manual* for more information on a specific function or method.

Getting information about a class

The following methods are used to obtain information about a class or to locate a particular class object:

somCheckVersion — Checks a class for compatibility with the specified major and minor version numbers. The receiver of the method is the SOM class about which information is needed. Additional arguments are values of the major and minor version numbers. The method returns TRUE if the class is compatible, or FALSE otherwise.

somClassFromId — Finds the class object of an existing class when given its **somId**, but without loading the class. The receiver of the method is the class manager (pointed to by the global variable **SOMClassMgrObject**). The additional argument is the class's **somId**. The method returns a pointer to the class (or NULL if the class does not exist).

somDescendedFrom — Tests whether one class is derived from another. The receiver of the method is the class to be tested, and the potential ancestor class is the argument. The method returns TRUE if the relationships exists, or FALSE otherwise.

somFindClass — Finds or creates the class object for a class, given the class's **somId** and its major and minor version numbers. The receiver of the method is the class manager (pointed to by the global variable **SOMClassMgrObject**). Additional arguments are the class's **somId** and the major and minor version numbers. The method returns a pointer to the class object, or NULL if the class could not be created.

somFindClsInFile — Finds or creates the class object for a class. This method is similar to **somFindClass**, except the user also provides the name of a file to be used for dynamic loading, if needed. The receiver of the method is the class manager (pointed to by the global variable **SOMClassMgrObject**). Additional arguments are the class's **somId**, the major and minor version numbers, and the file name. The method returns a pointer to the class object, or NULL if the class could not be created.

somGetInstancePartSize — Obtains the size of the instance variables introduced by a class. The receiver of the method is the class object. The method returns the amount of space, in bytes, needed for the instance variables.

somGetInstanceSize — Obtains the total size requirements for an instance of a class. The receiver of the method is the class object. The method returns the amount of space, in bytes, required for the instance variables introduced by the class itself and by all of its ancestor classes.

somGetName — Obtains the name of a class. The receiver of the method is the class object. The method returns the class name.

somGetNumMethods — Obtains the number of methods available for a class. The receiver of the method is the class object. The method returns the total number of currently available methods (static or otherwise, including inherited methods).

somGetNumStaticMethods
— Obtains the number of static methods available for a class. (A static method is one declared in the class's interface specification [.idl] file.) The receiver of the method is the class object. The method returns the total number of available static methods, including inherited ones.

somGetParent — Obtains a pointer to a class's parent (base) class. The receiver of the method is the class object. The method returns a pointer to the class's parent class object (unless the receiver is **SOMObject**, for which it returns NULL).

somGetParents — Obtains a list of the parent (base) classes of a specified class. The receiver of the method is the class object. The method returns a pointer to a linked list of the parent (base) classes (unless the receiver is **SOMObject**, for which it returns NULL).

somGetVersionNumbers — Obtains the major and minor version numbers of a class. The return type is void, and the two arguments are pointers to locations in memory where the method can store the major and minor version numbers (of type **long**).

somSupportsMethod — Indicates whether instances of a given class support a given method. The receiver of the **somSupportsMethod** method is the class object. The argument is the **somId** for the method in question. The **somSupportsMethod** method returns TRUE if the method is supported, or FALSE otherwise.

See the *SOMobjects Developer Toolkit: Programmers Reference Manual* for more information on a specific method.

Getting information about an object

The following methods and functions are used to obtain information about an object (instance) or to determine whether a variable holds a valid SOM object.

Methods

somGetClass — Gets the class object of a specified object. The receiver of the method is the object whose class is desired. The method returns a pointer to the object's corresponding class object.

somGetClassName — Obtains the class name of an object. The receiver of the method is the object whose class name is desired. The method returns a pointer to the name of the class of which the specified object is an instance.

somGetSize — Obtains the size of an object. The receiver of the method is the object. The method returns the amount of contiguous space, in bytes, that is needed to hold the object itself (not including any additional space that the object may be using or managing outside of this area).

somIsA — Determines whether an object is an instance of a given class or of one of its descendant classes. The receiver of the method is the object to be tested. An additional argument is the name of the class to which the object will be compared. This method returns TRUE if the object is an instance of the specified class or if (unlike **somIsInstanceOf**) it is an instance of any descendant class of the given class; otherwise, the method returns FALSE.

somIsInstanceOf — Determines whether an object is an instance of a specific class (but not of any descendant class).The receiver of the method is the object. The argument is the name of the class to which the object will be compared. The method returns TRUE if the object is an instance of the specified class, or FALSE otherwise.

somRespondsTo — Determines whether an object supports a given method. The receiver of the method is the object. The argument is the **somId** for the method in question. (A **somId** can be obtained from a string by using the **somIdFromString** function.) The **somRespondsTo** method returns TRUE if the object supports the method, or FALSE otherwise.

Functions

somIsObj — Takes as its only argument an address (which may not be valid). The function returns TRUE (1) if the address contains a valid SOM object, or FALSE (0) otherwise. This function is designed to be failsafe.

See the *SOMobjects Developer Toolkit: Programmers Reference Manual* for more information on a specific method or function.

Debugging

The following macros are used to conditionally generate output for debugging. All output generated by these macros is written using the replaceable character-output procedure pointed to by the global variable **SOMOutCharRoutine**. The default procedure simply writes the character to *stdout*, but it can be replaced to change the output destination of the methods and functions below. (See Chapter 5 for more information on customizing SOM.)

Debugging output is produced or suppressed based on the settings of three global variables, **SOM_TraceLevel, SOM_WarnLevel,** and **SOM_AssertLevel:**

- **SOM_TraceLevel** controls the behavior of the <*className*>**MethodDebug** macro;
- **SOM_WarnLevel** controls the behavior of the macros **SOM_WarnMsg**, **SOM_TestC,** and **SOM_Expect;** and
- **SOM_AssertLevel** controls the behavior of the **SOM_Assert** macro.

Available macros for generating debugging output are as follows:

<*className*>**MethodDebug**

— (macro for C and C++ programmers using the SOM language bindings for <*className*>)
The arguments to this macro are a class name and a method name. If the **SOM_TraceLevel** global variable has a nonzero value, the <className>**MethodDebug** macro produces a message each time the specified method (as defined by the specified class) is executed. This macro is typically used within the procedure that implements the specified method. (The SOM Compiler automatically generates calls to the <*className*>**MethodDebug** macro within the implementation template files it produces.) To suppress method tracing for all methods of a class, put the following statement in the implementation file after including the header file for the class:

```
#define <className>MethodDebug(c,m) \
                        SOM_NoTrace(c,m)
```

This can yield a slight performance improvement. The **SOMMTraced** metaclass, discussed below, provides a more extensive tracing facility that includes method parameters and returned values.

SOM_TestC — The **SOM_TestC** macro takes as an argument a boolean expression. If the boolean expression is TRUE (nonzero) and **SOM_AssertLevel** is greater than zero, then an informational message is output. If the expression is FALSE (zero) and **SOM_WarnLevel** is greater than zero, a warning message is produced.

SOM_WarnMsg — The **SOM_WarnMsg** macro takes as an argument a character string. If the value of **SOM_WarnLevel** is greater than zero, the specified message is output.

SOM_Assert — The **SOM_Assert** macro takes as arguments a boolean expression and an error code (an integer). If the boolean expression is TRUE (nonzero) and **SOM_AssertLevel** is greater than zero, then an informational message is output. If the expression is FALSE (zero), and the error code indicates a warning-level error and **SOM_WarnLevel** is greater than zero, then a warning message is output. If the expression is FALSE and the error code indicates a fatal error, then an error message is produced and the process is terminated.

SOM_Expect — The **SOM_Expect** macro takes as an argument a boolean expression. If the boolean expression is FALSE (zero) and **SOM_WarnLevel** is set to be greater than zero, then a warning message is output. If *condition* is TRUE and **SOM_AssertLevel** is set to be greater than zero, then an informational message is output.

See the *SOMobjects Developer Toolkit: Programmers Reference Manual* for more information on a specific macro.

The **somDumpSelf** and **somPrintSelf** methods can be useful in testing and debugging. The **somPrintSelf** method produces a brief description of an object, and the **somDumpSelf** method produces a more detailed description. See the *SOMobjects Developer Toolkit: Programmers Reference Manual* for more information.

Checking the validity of method calls

The C and C++ language bindings include code to check the validity of method calls at run time. If a validity check fails, the **SOM_Error** macro ends the process. (**SOM_Error** is described below.) To enable method-call validity checking, place the following directive in the client program prior to any *#include* directives for SOM header files:

```
#define SOM_TestOn
```

Alternatively, the **–DSOM_TestOn** option can be used when compiling the client program to enable method-call validity checking.

Exceptions and error handling

In the classes provided in the SOM run-time library (that is, **SOMClass, SOMObject,** and **SOMClassMgr**), error handling is performed by a user-replaceable procedure, pointed to by the global variable **SOMError**, that produces an error message and an error code and, if appropriate, ends the process where the error occurred. (Chapter 5 describes how to customize the error handling procedure.)

Each error is assigned a unique integer error code. Errors are grouped into three categories, based on the last digit of the error code:

SOM_Ignore — This category of error represents an informational event. The event is considered normal and can be ignored or logged at the user's discretion. Error codes having a last digit of 2 belong to this category.

SOM_Warn — This category of error represents an unusual condition that is not a normal event, but is not severe enough to require program termination. Error codes having a last digit of 1 belong to this category.

SOM_Fatal — This category of error represents a condition that should not occur or that would result in loss of system integrity if processing were allowed to continue. In the default error handling procedure, these errors cause the termination of the process in which they occur. Error codes having a last digit of 9 belong to this category.

The various codes for all errors detected by SOM are listed in Appendix A, "Customer Support and Error Codes."

When errors are encountered in client programs or user defined-classes, the following two macros can be used to invoke the error-handling procedure:

SOM_Error — The **SOM_Error** macro takes an error code as its only argument and invokes the SOM error handling procedure (pointed to by the global variable **SOMError**) to handle the error. The default error handling procedure prints a message that includes the error code, the name of the source file, and the line number where the macro was invoked. If the last digit of the error code indicates a serious error (of category **SOM_Fatal**), the process causing the error is terminated. (Chapter 5 describes how to customize the error handling procedure.)

SOM_Test — The **SOM_Test** macro takes a boolean expression as an argument. If the expression is TRUE (nonzero) and the **SOM_AssertLevel** is greater than zero, then an informational message is output. If the expression is FALSE (zero), an error message is produced and the program is terminated.

See the *SOMobjects Developer Toolkit: Programmers Reference Manual* for more information on a specific macro.

Other classes provided by the SOMobjects Toolkit (including those in the Persistence, Replication, DSOM, and Interface Repository frameworks, and the utility classes and metaclasses) handle errors differently. Rather than invoking **SOMError** with an error code, their methods return *exceptions* via the (**Environment ***) inout parameter required by these methods. The following sections describe the exception declarations, the standard exceptions, and how to set and get exception information in an **Environment** structure.

Exception declarations

As discussed in Chapter 4 in the section entitled “SOM Interface Definition Language,” a method may be declared to return zero or more exceptions. IDL exceptions are implemented by simply passing back error information after a method call, as opposed to the “catch/throw” model where an exception is implemented by a long jump or signal. Associated with each type of exception is a name, and optionally, a struct-like data structure for holding error information. A method declares the types of exceptions it may return in a **raises** expression.

Below is an example IDL declaration of a “BAD_FLAG” exception, which may be “raised” by a “checkFlag” method, as part of a “MyObject” interface:

```
interface MyObject {
   exception BAD_FLAG { long ErrCode; char Reason[80]; };

   void checkFlag(in unsigned long flag) raises(BAD_FLAG);
};
```

An exception structure contains whatever information is necessary to help the caller understand the nature of the error. The exception declaration can be treated like a **struct** definition: i.e., whatever you can access in an IDL **struct**, you can access in an **exception** declaration. Alternatively, the structure can be *empty*, whereby the exception is just identified by its name.

The SOM Compiler will map the exception declaration in the above example to the following C language constructs:

```
typedef struct BAD_FLAG {
   long ErrCode;
   char Reason[80];
} BAD_FLAG;

#define ex_BAD_FLAG "MyObject::BAD_FLAG"
```

When an exception is detected, the “checkFlag” method must call **SOMMalloc** to allocate a “BAD_FLAG” structure, initialize it with the appropriate error information, and make a call to **somSetException** (see “Setting an exception value,” below) to record the exception value in the **Environment** structure passed in the method call. The caller, after invoking “checkFlag”, can check the **Environment** structure that was passed to the method to see if there was an exception, and if so, extract the exception value from the **Environment** (see “Getting an exception value,” below.)

Standard exceptions

In addition to user-defined exceptions (those defined explicitly in an IDL file), there are several predefined exceptions for system run-time errors. A *system exception* can be returned on any method call. (That is, they are implicitly declared for every method whose class uses IDL call style, and they do not appear in any **raises** expressions.) The standard exceptions are listed in Table 2 of Section 4.5, “SOM Interface Definition Language”. Most of the predefined system exceptions pertain to Object Request Broker errors. Consequently, these types of exceptions are most likely to occur in DSOM applications (Chapter 6).

Each of the standard exceptions has the same structure: an error code (to designate the subcategory of the exception) and a completion status code. For example, the `NO_MEMORY` standard exception has the following definition:

```
enum completion_status {YES, NO, MAYBE};
exception NO_MEMORY { unsigned long minor;
                      completion_status completed; };
```

The completion status value indicates whether the method was never initiated (NO), completed execution prior to the exception (YES), or the completion status is indeterminate (MAYBE).

Since all the standard exceptions have the same structure, file “somcorba.h” (included by “som.h”) defines a generic **StExcep** typedef which can be used instead of the specific typedefs:

```
typedef struct StExcep {
     unsigned long minor;
     completion_status completed;
} StExcep;
```

The standard exceptions are defined in an IDL module called **StExcep**, in the file named “stexcep.idl”, and the C definitions can be found in “stexcep.h”.

The Environment

The **Environment** is a data structure that contains environmental information that can be passed between a caller and a called object when a method is executed. For example, it is used to pass information about the user id of a client, to return exception data to the client following a method call, and so on.

A pointer to an **Environment** variable is passed as an argument to method calls (unless the method’s class has the **callstyle=oidl** SOM IDL modifier). The **Environment** typedef is defined in “som.h”, and an instance of the structure is allocated by the caller in any reasonable way: on the stack (by declaring a local variable and initializing it using the macro **SOM_InitEnvironment**), dynamically (using the **SOM_CreateLocalEnvironment** macro), or by calling the **somGetGlobalEnvironment** function to allocate an **Environment** structure to be shared by objects running in the same thread.

For class libraries that use **callstyle=oidl**, there is no explicit **Environment** parameter. For these libraries, exception information may be passed using the per-thread **Environment** structure returned by the **somGetGlobalEnvironment** procedure.

Setting an exception value

To set an exception value in the caller’s **Environment** structure, a method implementation makes a call to the **somSetException** procedure:

**void somSetException (Environment ****ev*,
exception_type *major*,
string *exception_name*,
void ****params*);**

where “ev” is a pointer to the **Environment** structure passed to the method, “major” is an **exception_type,** “exception_name” is the string name of the exception (usually the constant defined by the IDL compiler, for example, `ex_BAD_FLAG`), and “params” is a pointer to an (initialized) exception structure which <u>must be allocated by **SOMMalloc**</u>**:**

```
typedef enum exception_type {
   NO_EXCEPTION, USER_EXCEPTION, SYSTEM_EXCEPTION
} exception_type;
```

It is important to reiterate that **somSetException** expects the *params* argument to be a pointer to a structure that was allocated using **SOMMalloc**. When **somSetException** is called, the client *passes ownership* of the exception structure to the SOM run-time environment. The SOM run-time environment will free the structure when the exception is reset (that is, upon the next call to **somSetException**), or when the **somExceptionFree** procedure is called.

Note that **somSetException** simply sets the exception value; it performs no exit processing. If there are multiple calls to **somSetException** before the method returns, the caller will only see the last exception value.

Getting an exception value

After a method returns, the calling client program can look at the **Environment** structure to see if there was an exception. The **Environment** struct is mostly opaque, except for an exception type field named **_major**:

```
typedef struct Environment {
   exception_type   _major;
   ...
} Environment;
```

If **ev._major != NO_EXCEPTION**, there was an exception returned by the call. The caller can retrieve the exception name and value (passed as parameters in the **somSetException** call) from an **Environment** struct via the following functions:

string somExceptionId (Environment ****ev*);**
somToken somExceptionValue (Environment ****ev*);**

The **somExceptionId** function returns the exception name, if any, as a string. The function **somExceptionValue** returns a pointer to the value of the exception, if any, contained in the exception structure. If NULL is passed as the **Environment** pointer in either of the above calls, an implicit call is made to **somGetGlobalEnvironment**.

The **somExceptionFree** procedure will free any memory in the **Environment** associated with the last exception:

void somExceptionFree (Environment ****ev*);**

Note**:** File “somcorba.h” (included by “som.h”) provides the following aliases for strict compliance with CORBA programming interfaces:

```
#ifdef CORBA_FUNCTION_NAMES
#define exception_id    somExceptionId
#define exception_value somExceptionValue
#define exception_free  somExceptionFree
#endif /* CORBA_FUNCTION_NAMES */
```

Example

Let us define an IDL interface for a “MyObject” object, which declares a “BAD_FLAG” exception, which can be raised by the “checkFlag”method, in a file called “myobject.idl”:

```
interface MyObject {
   exception BAD_FLAG { long ErrCode; char Reason[80]; };

   void checkFlag(in unsigned long flag) raises(BAD_FLAG);
};
```

The SOM IDL compiler will map the exception to the following C language constructs, in myobject.h:

```
typedef struct BAD_FLAG {
   long ErrCode;
   char Reason[80];
} BAD_FLAG;

#define ex_BAD_FLAG "MyObject::BAD_FLAG"
```

A client program that invokes the “checkFlag” method might contain the following error handling code. (Note: The error checking code below lies in the user-written procedure, “ErrorCheck,” so the code need not be replicated through the program.)

```
#include ”som.h”
#include ”myobject.h”

boolean ErrorCheck(Environment *ev);   /* prototype */

main()
{
   unsigned long flag;
   Environment ev;
   MyObject myobj;
   char     *exId;
   BAD_FLAG *badFlag;
   StExcep  *stExValue;

   myobj = MyObjectNew();
   flag  = 0x01L;
   SOM_InitEnvironment(&ev);

    /* invoke the checkFlag method, passing the Environment param */
   _checkFlag(myobj, &ev, flag);

   /* check for exception */
   if (ErrorCheck(&ev))
   {
      /* ... */
      somExceptionFree(&ev);   /* free the exception memory */
   }

   /* ... */
}


/* error checking procedure */

boolean ErrorCheck(Environment *ev)
{
   switch (ev._major)
   {
   case SYSTEM_EXCEPTION:
      /* get system exception id and value */
      exId      = somExceptionId(ev);
      stExValue = somExceptionValue(ev);
      /* ... */
      return(TRUE);

   case USER_EXCEPTION:
      /* get user-defined exception id and value */
      exId = somExceptionId(ev);
      if (strcmp(exId, ex_BAD_FLAG) == 0)
      {
         badFlag = (BAD_FLAG *) somExceptionValue(ev);
         /* ... */
      }
      /* ... */
      return(TRUE);

   case NO_EXCEPTION:
      return(FALSE);
   }
}
```

The implementation of the “checkFlag” method might contain the following error-handling code:

```
#include ”som.h”
#include ”myobject.h”

void checkFlag(MyObject somSelf, Environment *ev,
               unsigned long flag)
{
   BAD_FLAG *badFlag;
   /* ... */

   if ( /* flag is invalid */ )
   {
      badFlag = (BAD_FLAG *) SOMMalloc(sizeof(BAD_FLAG));
      badFlag->ErrCode = /* bad flag code */;
      strcpy(badFlag->Reason, ”bad flag was passed”);
      somSetException(ev, USER_EXCEPTION,
                      ex_BAD_FLAG, (void *)badFlag);
      return;
   }
   /* ... */
}
```

Memory management

The memory management functions used by SOM are a subset of those supplied in the ANSI C standard library. They have the same calling interface and the same return types as their ANSI C equivalents, but include supplemental error checking. Errors detected by these functions are passed to **SOMError** (described in the previous section). The correspondence between SOM memory management functions and their ANSI C standard library equivalents is shown below:

SOM Function	Equivalent ANSI C Library Routine
SOMMalloc	**malloc**
SOMCalloc	**calloc**
SOMRealloc	**realloc**
SOMFree	**free**

SOMMalloc, SOMCalloc, SOMRealloc, and **SOMFree** are actually *global variables* that point to the SOM memory management functions (rather than being the names of the functions themselves), so that users can replace them with their own memory management functions if desired. (See chapter 5 for a discussion of replacing the SOM memory management functions.)

SOM manipulations using somId’s

A **somId** is similar to a number that represents a zero-terminated **string**. A **somId** is used in SOM to identify method names, class names, and so forth. For example, many of the SOM methods that take a method or class name as a parameter require a value of type **somId** rather than **string**. All SOM manipulations using **somId**s are case insensitive, although the original case of the **string** is preserved.

During its first use with any of the following functions, a **somId** is automatically converted to an internal representation (registered). Because the representation of a **somId** changes, a special SOM type (**somId**) is provided for this purpose. Names and the corresponding **somId** can be declared at compile time, as follows:

```
string example = ”exampleMethodName”;
somId exampleId = &example;
```

or a **somId** can be generated at run time, as follows:

```
somId myMethodId;
myMethodId = somIdFromString(”exampleMethodName”);
```

SOM provides the following functions that generate or use a **somId**:

somIdFromString — Finds the **somId** that corresponds to a **string**. The method takes a **string** as its argument, and returns a value of type **somId** that represents the string. The returned **somId** must later be freed using **SOMFree.**

somStringFromId — Obtains the **string** that corresponds to a **somId**. The function takes a **somId** as its argument and returns the **string** that the **somId** represents.

somCompareIds — Determines whether two **somId** values are the same (that is, represent the same **string**). This function takes two **somId** values as arguments. It returns TRUE (1) if the **somId**s represent the same **string**, or FALSE (0) otherwise.

somCheckId — Determines whether SOM already knows a **somId**. The function takes a **somId** as its argument. It verifies whether the **somId** is registered and in normal form, registers it if necessary, and returns the input **somId**.

somRegisterId — The same as **somCheckId,** except it returns TRUE (1) if this is the first time the **somId** has been registered, or FALSE (0) otherwise.

somUniqueKey — Finds the unique key for a **somId.** The function takes a **somId** identifier as its argument, and returns the unique key for the **somId** — a number that uniquely represents the **string** that the **somId** represents. This key is the same as the key for another **somId** if and only if the other **somId** refers to the same **string** as the input **somId**.

somTotalRegIds — Finds the total number of **somId**s that have been registered, as an **unsigned long**. This function is used to determine an appropriate argument to **somSetExpectedIds**, below, in later executions of the program. The function takes no input arguments.

somSetExpectedIds — Indicates how many unique **somId**s SOM can expect to use during program execution, which, if accurate, can improve the space and time utilization of the program slightly. This routine must be called before the SOM run-time environment is initialized (that is, before the function **somEnvironmentNew** is invoked and before any objects are created). This is the only SOM function that can be invoked before the SOM run-time environment is initialized. The input argument is an **unsigned long**. The function has no return value.

somBeginPersistentIds and **somEndPersistentIds**
— Delimit a time interval for the current thread during which it is guaranteed that (a) any new **somId**s that are created will refer only to static strings and (b) these strings will not be subsequently modified or freed. These functions are useful because **somId**s that are registered within a "persistent ID interval" can be handled more efficiently.

See the *SOMobjects Developer Toolkit: Programmers Reference Manual* for more information on a specific function.