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BETTER APPLE EVENT CODING THROUGH OBJECTS

ERIC M. BERDAHL

In “Apple Event Objects and You” in develop Issue 10, Richard Clark discusses a procedural approach to programming for Apple events and goes into details of the Apple event object model. This article reveals a few simple truths about the significance of Apple events and the Apple event object model, focusing on how the object model maps onto a typical object-oriented application. It also provides an object-oriented C++ framework for adding scripting support. It's every developer's worst nightmare: Your team has just spent the last two years putting the finishing touches on the latest version of Turbo WhizzyWorks II NT Pro, which does everything, including make coffee. As a reward for your great work, the team is now preparing to do some serious tanning development on an exotic island. Then, Marketing comes in with “one last request.” They promise it's the last thing they'll ask for before shipping, and in a weak moment, you agree that one last little feature won't hurt your itinerary. “Good,” quips the product manager, “then as soon as you add full scripting support, you can enjoy your vacation.”

You know that to add scripting support, you need to delve into Apple events. You think this requires learning about Apple events, the Apple event object model, and scripting systems. Further, you think Apple events must be designed into your application from the ground up and can't possibly be added without a complete redesign. Which of the following is the appropriate reaction to Marketing's request?

- A. Immediately strangle your sales manager and plead justifiable homicide.
- B. Look around while laughing hysterically and try to find the hidden Candid Camera.
- C. Change jobs.
- D. Feign deafness.
- E. None of the above.

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Unfortunately, there's no correct answer, but the scenario is all too real as developers are increasingly being asked to add scripting support to their applications. The design of Apple events and the Apple event object model can provide the user with more power than any other scripting system. However, to access the power of the design you need to work with the complex interface provided by the Apple Event Manager. By its nature, this interface collapses to a procedural plane of programming that prevents developers from fully taking advantage of the object-oriented design inherent in the Apple event world. The Apple event object model is difficult to implement without some fancy footwork on the part of your framework. But remember the words of Marshall Brodeen, "All magic tricks are easy, once you know the secret." With this in mind, join me on a trip through the rabbit hole into AppleEventLand.

WHAT ARE APPLE EVENTS AND THE OBJECT MODEL?

Whenever I give presentations on Apple events, the audience has an overwhelming urge to ignore the theory and jump into coding. Resist the urge. For most developers Apple events provide an unfamiliar perspective on application design. To appreciate the significance of Apple events and the object model, it's important to understand their underlying concepts and background. So, although you'll be reading about code later, a little theory needs to come first.

At the most basic level, Apple events are a program-to-program communication (PPC) system, where *program* is defined as a piece of code that the Macintosh can see as an application (in other words, that has a real `WaitNextEvent`-based event loop). However, billing Apple events as PPC is akin to describing an F-16 as merely a plane. To fully understand how Apple events are more than simple program-to-program communication, you need to take a look at the Apple event object model.

The object model isn't really defined in a pithy paragraph of *Inside Macintosh*, but is instead a holistic approach to dealing with things that users call objects. In a literal sense, the object model is a software developer's description of user-centric objects or *cognitive objects*.

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COGNITIVE THEORY

Cognitive science tells us that people interact with the world through objects. A printed copy of *develop* is an object, a plant in the corner of your office is an object, and a can of Coke Classic on your desk is an object. Each of the objects has properties, behaviors, and parts. Some properties exist for each of the objects (for example, each one has a *name*) and other properties make sense for only some of the objects (for example, *page size* makes sense only when applied to *develop*). Behaviors are quite similar to properties in their ephemeral binding to objects. Only Coke will *fizz*, but all three objects will *decompose*. However, they each *decompose* in a different way. Further, each object can be separated into arbitrary parts that are themselves objects. The plant can be separated into branches, which can in turn be separated

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into leaves. The plant itself can also be separated into leaves, so leaves are contained by both branch objects and plant objects.

BACK INSIDE THE COMPUTER

Now, since a user will someday interact with your software, and since users interact with the world in terms of cognitive objects, it makes sense to model software in terms of cognitive objects. Hence, the object model describes objects in a rather ghostlike fashion whereby objects have behaviors and properties and contain other objects. Although the object model defines an inheritance for each category of objects (for example, `Journal` might inherit from `OpenableThing` which might inherit from `Object`), it's used only for the purpose of grouping similar behaviors. Just as in the mind, the only thing that's important is the identity of a specific object in existence at a given time — its categorization is purely a detail of implementation.

Gee, this sounds a lot like what *real* programmers mean when they talk about objects. Strangely enough, real objects and cognitive objects are quite related. Many references cite cognitive theory as justification for beginning to program in an object-oriented style. Object-oriented code tries to get closer to the language of the native operating system of the human mind than traditional procedural approaches, and the format of an Apple event object mirrors natural language to a surprisingly large degree. It comes as no surprise, then, that Good Object Design lends itself quite easily to slipping in support for Apple event scripting.

APPLE EVENTS SCRIPTING AND OBJECTS

The motivation for you to provide object model support is so that your users can “script” your application. There are a variety of solutions available today that allow advanced users to write things that resemble DOS batch files or UNIX® shell scripts. These entities are commonly called *scripts*, but in the context of Apple events a script is something with greater potential. Whenever a user thinks “I want to sharpen the area around the rose in this picture,” a script has been formed. If this seems too simplistic, consider it again. *Script* here refers to the earliest conception of a user's intent to do something. It's not relegated to the world of the computer and does not imply any given form or class of forms; an oral representation (voice interface a la the Knowledge Navigator) is equally as valid as a written one (traditional scripting systems). From this perspective, the definition of *script* takes the user to a greater depth of control over applications than previously dreamed of, allowing access to the very engine of your application by the very engine of the user. This is the great empowering ability of Apple events: they enable users to use their native operating system — the mind — with little or no translation into computerese.

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OBJECT-ORIENTED PROGRAMMING OBJECTS

The biggest problem with Apple event objects is the interface provided by the Apple Event Manager.
Instead of allowing you to write real object-oriented source code

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using a given class library that implements basic Apple event and object model functionality, the Apple Event Manager requires you to register every detail programmatically. You must declare what classes exist, which methods exist and where, and what relationships are possible within and between classes. Although at first this flexibility seems advantageous, many developers find it a problem later when they have to declare everything again at run time. Anyone with secret desires to design an object-oriented runtime environment and a compiler/linker combination to support that environment will feel quite at home with Apple event coding.

The second biggest problem with Apple event objects is that programs aren't written in the Apple event (user) world. Instead, they're often written in object-oriented programming languages like LISP and C++. What's needed is a good generic interface to translate objects from the user world of natural language into the world of LISP or C++ objects. Scripting systems do some of the work by delivering Apple event objects to applications in the form of object specifiers, a strange data structure that resembles a binary form of natural language stuffed into the familiar Apple event generic data structure AEDesc. However, object-oriented applications ship objects around in the form of . . . well . . . objects! So, you need translation from binary natural language to actual objects. Easy, huh? (Don't hurt me yet — this will seem fairly straightforward after reading a bit further.)

Presenting a new interface should solve the problem of the Apple Event Manager interfaces. Presenting that new interface in terms of the familiar object-oriented class libraries should solve the problem of different paradigms. So, if these two problems are approached with an object perspective, it's clear that some of the classes in your program need to include a set of methods that implement object model protocols. Application domain classes must be able to return objects contained within them and to perform generic operations on themselves. It turns out that if your classes also provide the ability to count the number of a specific type of object they contain, you can provide a rudimentary, yet powerful, parsing engine for transforming objects from the Apple event world into the traditional object programming world.

Further analysis indicates that only those application domain classes that correspond to object model classes need this protocol. This indicates that the protocol for providing Apple event object model support is probably appropriate to provide in a mixin class (a class that's meant to be multiply inherited from). In this way, only those classes that need to provide object model support must provide the necessary methods. In the sample application discussed later, that class is called MAppleObject. MAppleObject plays a key role in UAppleObject, a generic unit that can be used to provide Apple event object model support to any well-designed C++ application.

Apple provides a convenient solution to the user versus programming language problem in the form of the Object Support Library (OSL). The OSL has the specific responsibility of turning an object specifier into an application's internal representation of an object. (See "A Sample OSL Resolution" for an example of how A SAMPLE OSL RESOLUTION

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Here's a short example to give you a feel for how the OSL actually works. Don't read too much into the details of object resolution, but do try to understand the flow and methodology the OSL applies to resolve object specifiers. Also, don't worry too much about how the OSL asks questions; the protocol you'll actually be using in UAppleObject hides such details from you.

Figure 1 on the next page gives an overview of the process. Consider the simple object specifier "the third pixel in the first scan line of the image called 'Girl with Hat,'" and an Apple event that says "Lighten the third pixel in the first scan line of the image called 'Girl with Hat' by twenty gray levels." On receiving this Apple event (Lighten) the application notes that the direct object of the event (the third pixel in the first scan line of the image called "Girl with Hat") is an object specifier and asks the OSL to resolve it into a real object.

At this point the parsing engine in the OSL takes over, beginning a dialog with your application through a set of preregistered callback routines. Notice that the object specifier bears a striking resemblance to a clause of natural language — English in this case. This is not unintentional. Apple event objects are cognitive objects, and cognitive objects are described by natural language — hence the parallels between object specifier formats and natural language. Further, the parsing engine inside the OSL operates like a high school sophomore parsing sentences at the chalkboard. But I digress . . .

To continue, the OSL asks the null object to give it a token for the image called "Girl with Hat." (Tokens are the Coin

of the Realm to the OSL.) So the null object looks through its images to find the one named "Girl with Hat" and returns a token to it.

The OSL then turns around and asks the image called "Girl with Hat" to give it a token for the first scan line. After getting this token, the OSL has no further use for the image token, so it's returned to the application for disposal. In effect, this says, "Uh, hey guys, I'm done with this token. If you want to do anything like free memory or something, you can do it now." Notice how polite the OSL is.

Next, the OSL asks the scan line for a token representing the third pixel, which the line handily returns. Now it's the scan line token's turn to be returned to the application for recycling. The OSL has no further use for the scan line token, so the application can get rid of it if necessary.

Finally, having retrieved the token for the third pixel of the first line of the image called "Girl with Hat," the OSL returns the token with a "Thanks, and come again." The application can then ask the object represented by the token to lighten itself (remember that was the original Apple event), and dispose of the token for the pixel.

As you can see, the OSL operates by taking an unreasonable request, "give me the third pixel of the first line of the image called "Girl with Hat," and breaks it into a number of perfectly reasonable requests. Thus, your application gets to take advantage of its innate knowledge of its objects and their simple relationships to answer questions about complex object relationships.

the OSL actually works.) The OSL implements a generic parsing engine, applying a few simple assumptions about the state of the application's design to the problem. However, for all the power provided by the engine within the OSL, it lacks an object-oriented interface. Instead, it uses a paradigm like that provided by the Apple Event Manager, requiring the application to register a set of bottleneck routines to provide application-specific functionality. As with the Apple Event Manager, you must write routines that implement runtime dispatching to the individual objects your application creates instead of using the natural method-dispatching mechanisms found in your favorite object-oriented language, whatever it may be.

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The nicest thing about the OSL is that, like the Apple Event Manager itself, it applies itself quite well to being wrapped with a real object-oriented interface (although you have to write it yourself, sigh). Curiously, the OSL solves both problems — poor interface and cognitive versus object-oriented programming differences. With a nice object-oriented framework, you can write your code once, in the fashion to which you're accustomed. I won't lie to you by telling you the job becomes easy, but it does change from obscure and harrowing to straightforward and tedious.

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OBJECT MODEL CONCEPTS

There are two basic concepts defined in the object model. One is *containment*, which means that every object can be retrieved from within some other object. In the language of the object model, every object is *contained by* another object. The only exception to this rule is the single object called the *null object*. The null object is commonly called the *application object*, and may or may not be contained by another object. In practice, a null object specifier is like a global variable defined by the object model. The application implicitly knows which object is meant by “null object.” Object resolution always begins by making some query of the null object.

For example, with a simple image processor, it would be appropriate to state that pixels are contained by scan lines, scan lines by images, and images by windows. It's also appropriate to have pixels contained by images and windows. Windows themselves have no natural container, however. Therefore, they must be contained by the null object. One way you can decide whether these relationships make sense for your product is to ask if a user could find it useful to do something to “the eighth pixel of the second scan line” or to “the twentieth pixel of the image.” If statements like these make sense, a containment relationship exists.

The second basic concept of the object model is *behavior*. Behavior is quite simple; it means that objects must be able to respond to an Apple event. Behavior correlates directly with the traditional object programming concept of methods of a class. In fact, as you'll see, the actual Apple event-handling method of Apple event objects is usually a switch statement that turns an Apple event into a dispatch to the C++ method that implements the Apple event's functionality.

Taken together, the concepts of containment and behavior define the limits for objects in the model of the Apple event world. The object model resembles the programming worlds of Smalltalk or LISP, where everything is an object. Everything. For those familiar with these paradigms where even integers, characters, and floating-point numbers are full first-citizen objects, the Apple event world will be a refreshing change from traditional programming in C++ and Pascal.

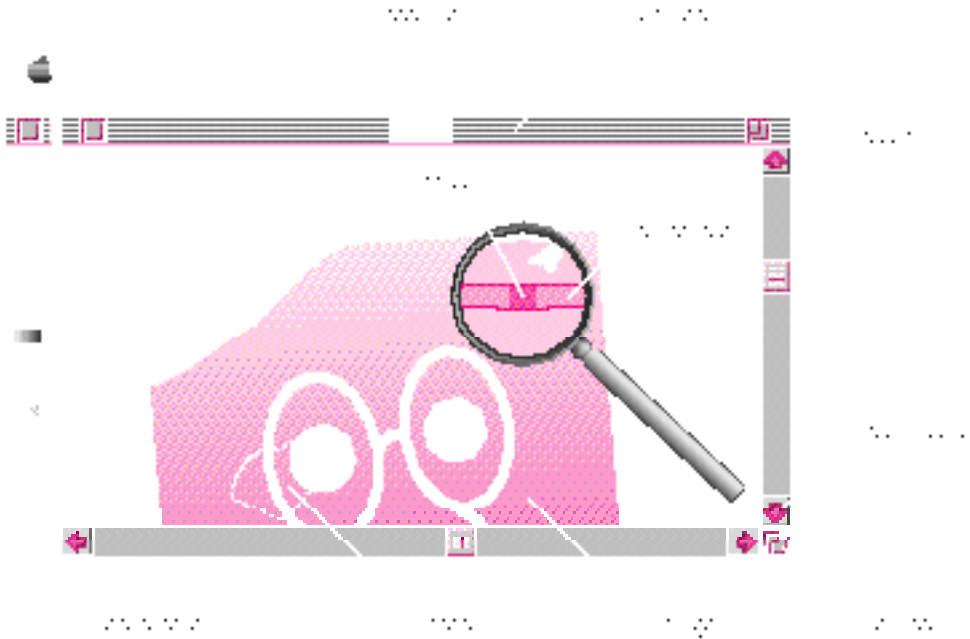
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FINDING THE OBJECTS

The overriding concept in designing object model support in your application is to do what makes sense for both you — as the developer — and the user.

1. It's best to begin by deciding what objects exist in your application. To decide what objects exist, do some user testing and ask the users what objects they see and what objects they think of while using your application. If this isn't possible, just pretend you're a user and actually use your application, asking yourself those same questions. For example, if you ask users for a list of objects in an image processing application (and refrain from biasing them with computer mumbo jumbo) they'll probably list such things as window, icon, image, pixel, area, scan line, color, resolution, and menu bar. (Figure 2 shows types of objects a user might list.) Guess what? In reality, those probably are object model classes that an image processing application could support when it supports the object model. Since the objects you'll want to support are user-level kinds of entities, this makes perfect sense.



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Figure 2
Objects the User Sees

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2. After deciding what objects exist in your application, run another series of user tests to determine the relationships between different objects. For example, what objects does a window contain? Menus? Pixels? Areas? Color? What objects does an area contain? Pixels? Scan lines? Windows? This is just as simple as it seems. Just ask the question, “Does this object contain that object?” If you get immediate laughter, move on. Positive answers or thoughtful looks indicate a possible relationship.
3. Finally, determine what properties and behaviors each object class will have. These questions can be asked during the same user test as in step 2 because the answers users will give are closely related. Will you be able to ask windows for their names or pixels for their colors? How about asking windows to move or close? Can you ask pixels to change color or make a copy?

You may have noticed that this approach falls into the category of Good Object Design. Undoubtedly, anyone who does object-oriented design has gone through a similar process when developing an application. Resist the temptation to design the application's internal structure using G.O.D. and be done with it, because the object model design is different from the application design. When designing the application, you typically analyze structure from the perspective of eventually implementing the design. Thus, you impose design constraints to make implementation easier. For example, you probably don't keep representations of images, areas, and pixels, but choose one model for your internal engine — a reasonable solution for a programmer looking at the problem space. A typical image processing program usually has real classes representing images, and probably has an area class, but may not have a pixel class or scan line class. Pixels and scan lines may be implemented by a more basic representation than classes — simple indices or pointers into a `Pixmap`, for example.

However, when you design object model support, you have a very different perspective. You're designing classes based on user expectation and intention, not on programmer constraints. In object model design of an image processor, you *do* have `TImage`, `TArea`, `TScanLine`, and `TPixel` classes, regardless of your internal representation. This is because a user *sees* all these classes. The `TImage` and `TArea` may be the same as your internal engine's `TImage` and `TArea`, and probably are. After all, there's little reason to ignore a perfectly usable class that already exists. However, the `TPixel` and `TScanLine` classes exist only to provide object model support. I call classes that exist only to provide object model support *ephemeral* classes.

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Undeniably, the most useful tool for finding objects is user testing. Another important source of information is the Apple Event Registry. The Apple Event Registry describes Apple event classes that are standardized in the Apple event world. The Registry lists each class along with its inheritance, properties, and behaviors. It's also the last word on the values used to code object model support. For example,

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constants for predefined Boolean operators and class types are listed in detail. As you follow the process for finding the objects in your application, you can use the elements found in the Registry as a basis for your investigation and for later implementation. For example, if your user tests reveal that a pixel class is appropriate for your application and a Pixel class is documented in the Registry, you should probably use the behaviors and properties documented there as a basis for your application's TPixel class. Doing so allows your application to work well with existing scripts that manipulate pixels and allows your users to have a consistent scripting experience across all pixel-using applications.

OSL CONCEPTS

In addition to the principles imposed by the object model itself, the OSL makes a few reasonable assumptions about what applications provide to support their objects. Since the object model requires that objects be able to retrieve contained objects, the OSL allows an object to count the number of objects of a given type contained within them. So, if an image contains scan lines, the image object needs to be able to count the number of scan line objects contained within it. Of course, in some circumstances, the number of objects that are contained can't be counted or is just plain big (try asking how many TSand objects are contained in a TBeach object). In this case, the OSL allows the object to indicate that the number can't be counted.

Additionally, the OSL allows applications to apply simple Boolean operators to two objects. The operators themselves are a part of the *Apple Event Registry*. They include the familiar operators like less than, equal to, and greater than as well as some more interesting relations like before, after, over, and under. The requirement for these operators is that they have Boolean results. This means that if *object1* and *object2* have *operator* applied to them, the expression *object1 operator object2* is either true or false. Of course, there's no requirement that every class implement every operator, only those that make sense. It makes little sense to ask if an object of type TColor is *greater than* another, but *brighter than* is another story.

During resolution of an Apple event, the OSL asks for tokens of objects between the application object and the final target to be returned (as described earlier in this article in "A Sample OSL Resolution"). To a programmer, they look like AEDescs being passed around, but the OSL treats them specially:

- The OSL guarantees that it will never ever look in the data portion of the token, the dataHandle field of the AEDesc. It may peek at the descriptorType field from time to time, but the data itself is golden. This becomes a critical point when applying the OSL engine to an object-oriented interface. The token data of Apple event objects should be "real" object references in whatever programming language is appropriate, and keeping the data completely private to the application makes this possible.

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- The application must be able to recognize the token when it appears again. Thus, if the application returns a token for the image “Girl with Hat” to the OSL, the application must be able to recognize the significance of having that token passed back by the OSL.
- The OSL asks only that we guarantee the validity of a token during the resolution of the current object specifier.

Since the data contained in the AEDescs is private, the OSL must provide a system for the application to know when a token is being created and when it's being terminated. Creation of tokens is provided through the containment accessor protocol. Termination is provided by a callback routine which does the actual token disposal and which the application registers with the OSL. This callback is invoked from AEDisposeToken and comes in handy when applying the object model to C++ classes.

There are also a number of features that are beyond the scope of this article. One of these is the OSL concept of *marking* objects. This means that objects are labeled as belonging to a particular group. The contract the OSL makes with the application is that the OSL will ask whenever it needs a new kind of mark, and the application will recognize whether any object is marked with a particular mark. Further, given the mark itself, the application will be able to produce all the objects with that mark. If this sounds particularly confusing, just consider mark objects as typical list objects. Given a list and an object, it's quite natural to answer the question, “Is this object in this list?” Further, it's quite natural to answer the question, “What are all the objects contained in this list?”

The framework for adding Apple event support described later in the section “Inside UAppleObject” satisfies the basic OSL requests for counting objects, applying Boolean operators, and handling tokens. However, it doesn't handle marks. The intrepid reader could add support for this feature with a little thought.

CLASS DESIGN

To incorporate object model support into your applications, you need a class library that implements the object model classes you want to support — for example, the TWindow, TImage, TArea, and TPixel classes described earlier. These classes exist because they represent Apple event objects the application will support. Then you create a mapping of Apple event objects to the C++ classes that implement them (see Figure 3). For the sake of argument, say that TWindow, TArea, and TImage are also part of the class library used to implement the non-object-model portions of the program. The TPixel class is an ephemeral class. What these four classes have in common is a mixin class, MAppleObject, that provides the hooks for adding object model functionality (see the next section, “Inside UAppleObject,” for more details).

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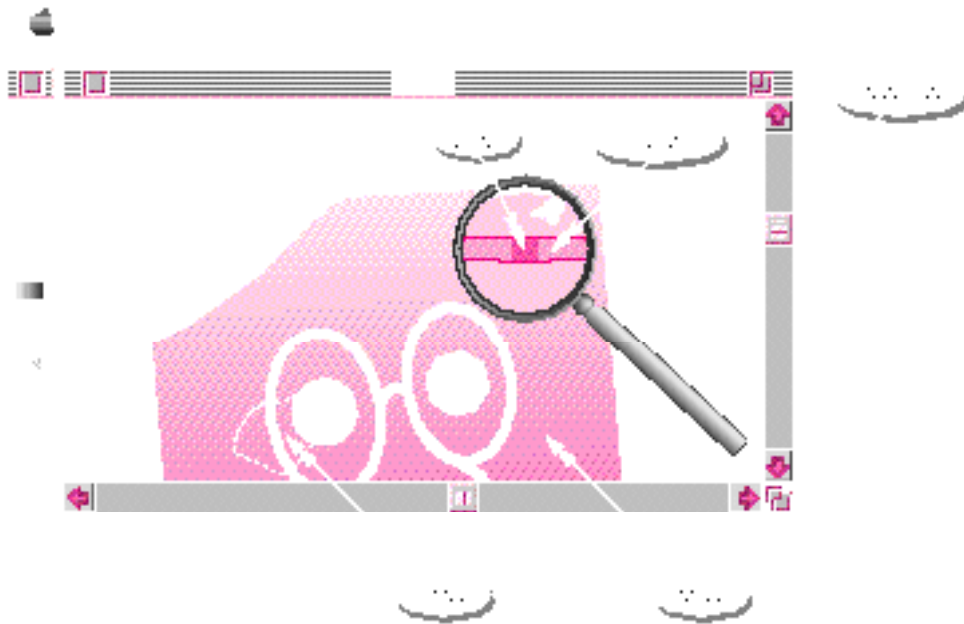


Figure 3
 The Objects As Implemented

MAppleObject must include protocol that implements the object model and OSL concepts. Given an MAppleObject, there should be protocol for returning an object contained within MAppleObject. This accessor method is expected to return an object that satisfies the containment request. It also needs to inform the framework if the returned object is an ephemeral object — some might say that such an object is *lazy evaluated* into existence. As a practical matter, this informs the framework whether an object needs to be deleted when the OSL disposes of the object's token (as described in “A Sample OSL Resolution”). Obviously, it would be undesirable to have the framework delete the TImages because the application depends on them for its internal representation. It would be equally stomach-turning to have all the TPixels pile up in the heap, never to be deleted.

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Since TPixel objects don't actually exist until they're lazy evaluated into existence, you're free to design their implementation in a wide variety of ways. Remember that one of the contracts the OSL makes with the application is that tokens need to be valid only during the resolution of the current object specifier. Well, consider that the implementation of images is just a handle of gray values. Normally, if someone suggested that a pixel be implemented as an index into a block of data, you'd throw temper tantrums. "What!" you'd yell, "What if the pixel is moved in the image! Now the index is stale." This is not an issue for tokens, because they're transient. Since pixels won't be added during the resolution of an object specifier, such a

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representation is fine. Of course, if you'd prefer a more robust implementation, that's fine, too, but remember that the OSL doesn't impose such robustness on you.

MAppleObject must also include a protocol to implement the comparison operators, counting protocol, and behavior dispatching. As a practical matter, these methods will likely be large switch statements that call other, more meaningful, methods depending on the details of the request. For example, the counting protocol might key on the kind of objects that should be counted and invoke methods specialized to count contained objects of a specific class.

Finally, each class provides protocol for telling clients which object model class the object represents. This is necessary for the framework to be able to communicate with the OSL. During the resolution conversation the OSL holds with the framework, the framework returns descriptors of each object the OSL asks for. These descriptors are required to publish to the OSL the type of the object returned from the request.

INSIDE UAPPLEOBJECT

UAppleObject is a framework whose main contribution is the class MAppleObject. MAppleObject provides the basis for integrating Apple event objects and Apple event object support into object-oriented applications. UAppleObject also includes a dispatcher, TAppleObjectDispatcher, and the 'aedit' resource. You drop the UAppleObject files into your application and immediately begin subclassing to provide Apple event functionality.

EXCEPTION HANDLING IN UAPPLEOBJECT

Developers familiar with the details of Apple event implementation are no doubt aware that the Apple Event Manager deals exclusively with error code return values, as does the rest of the Toolbox. When the Apple Event Manager invokes a developer-supplied callback routine, that routine commonly returns an integer error code. This style of error handling is found nowhere in UAppleObject. Instead, UAppleObject uses the UMAFailure unit to provide exception handling. UMAFailure is a unit available on the *Developer CD Series* disc that provides both a MacApp-style exception-handling mechanism for non-MacApp programs and excellent documentation for its use.

Wherever UAppleObject is invoked through a callback routine that expects an error code to be returned, all exceptions are caught and the exception's error code is returned to the Toolbox. Therefore, when an error occurs, call the appropriate FailXXX routine provided by UMAFailure — for example FailMemError, FailNIL, or FailOSErr. In the UAppleObject documentation, calling one of these routines is referred to as throwing an exception.

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MAPPLEOBJECT

The major workhorse of UAppleObject is MAppleObject, an implementation of the basic Apple event object functionality. MAppleObject is an abstract mixin class that provides the protocol necessary for the UAppleObject framework to resolve Apple event objects and handle Apple events.

```
class MAppleObject
{
public:
    MAppleObject();
    MAppleObject(const MAppleObject& copy);
    virtual ~MAppleObject();

    MAppleObject& operator=(const MAppleObject& assignment);

    virtual DescType GetAppleClass() const = 0;

    virtual long CountContainedObjects(DescType ofType);
    virtual MAppleObject* GetContainedObject(DescType desiredType,
        DescType keyForm, const AEDesc& keyData, Boolean& needDisposal);
    virtual Boolean CompareAppleObjects(DescType compareOperator,
        const MAppleObject& toWhat);
    virtual void DoAppleEvent(const AppleEvent& message,
        AppleEvent& reply, long refCon);

    static void SetDefaultAppleObject(MAppleObject* defaultObject);
    static MAppleObject* GetDefaultAppleObject();

    static void GotRequiredParameters(const AppleEvent& theAppleEvent);

    static void InitAppleObject(TAppleObjectDispatcher* dispatcher = nil);
};
```

GetAppleClass

```
DescType GetAppleClass() const = 0;
```

GetAppleClass is an abstract method that returns the object model type of an object. Every MAppleObject subclass should override this method to return the object model type specific to the individual object.

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CountContainedObjects

```
long CountContainedObjects (DescType ofType) ;
```

CountContainedObjects should return the number of objects of the indicated type that are contained within the receiver object. This is usually done by counting the

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number of objects your subclass knows how to access and adding it to the number
 of objects the parent class finds (in other words, call the inherited version and add it to the number you
 find yourself). If the number of objects is too large to be enumerated in a signed 16-bit integer,
 CountContainedObjects may throw the errAEIndexTooLarge exception.

GetContainedObject

```
MApplableObject* GetContainedObject(DescType desiredType, DescType keyForm,
    const AEDesc& keyData, Boolean& needDisposal);
```

GetContainedObject is a generic method for obtaining an object contained by the receiver. Subclasses
 always override this method to provide access to the subclass's contained objects. The desiredType,
 keyForm, and keyData arguments indicate the specific object to be returned as the function result. If
 the resulting object is one used in the framework of the application, GetContainedObject should return
 false in the needDisposal argument.

The alternative is for GetContainedObject to create the resulting object specifically for this request; in
 this case, it returns true in the needDisposal argument. If needDisposal is true, the UAppleObject
 framework deletes the result object when it's no longer needed.

CompareAppleObjects

```
Boolean CompareAppleObjects(DescType compareOperator,
    const MAppleObject& toWhat);
```

CompareAppleObjects performs the logical operation indicated by the arguments, returning the
 Boolean value of the operation. The semantics of the operation
 is *this compareOperator toWhat*. So, if the compareOperator parameter were kAEGreaterThan, the
 semantics of the method call would be *this is greater than toWhat*. Subclasses always override this
 method to provide the logical operations
 they support.

DoAppleEvent

```
void DoAppleEvent(const AppleEvent& message, AppleEvent& reply,
    long refCon);
```

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When an object is identified as the target of an Apple event, it's sent the DoAppleEvent message. The message and reply Apple event records are passed in the corresponding arguments. If the direct parameter to the message is typeObjectSpecifier, the object specifier is guaranteed to resolve to the receiver; otherwise the receiver is the application object. Additional modifiers for the event can be extracted from the message, and the reply should be filled in by DoAppleEvent, if appropriate. The refCon parameter is the shortcut number registered with the UAppleObject framework (see the section "The 'aedt' Resource"). Subclasses always

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override DoAppleEvent to dispatch their supported Apple events to appropriate methods.

SetDefaultAppleObject and GetDefaultAppleObject

```
void MAppleObject::SetDefaultAppleObject(MAppleObject* defaultObject);  
MAppleObject* MAppleObject::GetDefaultAppleObject();
```

GetDefaultAppleObject returns the MAppleObject currently registered as the null container. Similarly, SetDefaultAppleObject registers a particular object as the null container. Usually, the object serving as null container doesn't change during the lifetime of the application — it's always the application object. In this case, just call SetDefaultAppleObject from within your application object's constructor. But remember that any Apple event that arrives when no null container is registered falls on the floor and is returned to the Apple Event Manager with the errAEEEventNotHandled error.

GotRequiredParameters

```
void MAppleObject::GotRequiredParameters(const AppleEvent&  
    theAppleEvent);
```

GotRequiredParameters is here for convenience. To do Apple event processing “right,” each Apple event handler should check that it has received everything the sender sent. Almost every good Apple event sample has this routine and calls it from within the handlers. Since all handling is done from within an MAppleObject method, it makes sense for this protocol to be a member function of MAppleObject. However, the member function really doesn't need access to the object itself, and could actually be called from anywhere, so it's a static member function.

InitAppleObject

```
void MAppleObject::InitAppleObject(TAppleObjectDispatcher* dispatcher =  
    nil);
```

InitAppleObject must be called once after the application initializes the Toolbox and before it enters an event loop (specifically, before WaitNextEvent gets called). This method installs the given object dispatcher, or creates a TAppleObjectDispatcher if nil is passed.

TAPPLEOBJECTDISPATCHER

The second element of UAppleObject is TAppleObjectDispatcher. Together with MAppleObject, TAppleObjectDispatcher forms a complete model of Apple events, the objects themselves, and the Apple event engine that drives the object protocol. TAppleObjectDispatcher is responsible for intercepting Apple events and directing them to the objects that should handle them. A core feature of this engine is the ability to resolve object specifiers into “real” objects.

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```
class TAppleObjectDispatcher
{
public:
    TAppleObjectDispatcher();
    virtual ~TAppleObjectDispatcher();

    virtual void Install();

    virtual MAppleObject* ExtractObject(const AEDesc& descriptor);
    virtual void StuffDescriptor(AEDesc& descriptor, MAppleObject* object);

    virtual void HandleAppleEvent(const AppleEvent& message,
        AppleEvent& reply, long refCon);

    virtual void AccessContainedObjects(DescType desiredClass,
        const AEDesc& container, DescType containerClass, DescType form,
        const AEDesc& selectionData, AEDesc& value, long refCon);
    virtual long CountObjects(const AEDesc& containerToken,
        DescType countObjectsOfType);
    virtual Boolean CompareObjects(DescType operation, const AEDesc& obj1,
        const AEDesc& obj2);
    virtual void DisposeToken(AEDesc& unneededToken);

    virtual MAppleObject* GetTarget(const AppleEvent& message);

    virtual void SetTokenObjectDisposal(MAppleObject* tokenObject,
        Boolean needsDisposal);
    virtual Boolean GetTokenObjectDisposal(const MAppleObject*
        tokenObject);

    virtual MAppleObject* ResolveSpecifier(AEDesc& objectSpecifier);

    virtual void InstallAppleEventHandler(AEEventClass theClass,
        AEEventID theID, long refCon);

    static TAppleObjectDispatcher* GetDispatcher();
};
```

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Install

```
void Install();
```

Install is called when the dispatcher object is actually installed (at InitAppleEvent time). It's responsible for reading the 'aedt' resources for the application and declaring the appropriate handlers to the Apple Event Manager as well as registering with the OSL. Overrides should call the inherited version of this member function

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to maintain proper functionality. This method may be overridden to provide functionality beyond that supplied by `TAppleObjectDispatcher` — to provide for mark tokens, for example, which are left as an exercise for the reader. (Don'tcha just hate it when articles do this to you?)

ExtractObject and StuffDescriptor

```
MAAppleObject* ExtractObject(const AEDesc& descriptor);  
void StuffDescriptor(AEDesc& descriptor, MAAppleObject* object);
```

One of the key abstractions provided by `TAppleObjectDispatcher` is the packaging of `MAAppleObjects` into tokens for communication with the Apple Event Manager and OSL. `ExtractObject` and `StuffDescriptor` are the pair of routines that carry the responsibility for translation. `ExtractObject` returns the `MAAppleObject` contained within the token descriptor, while `StuffDescriptor` provides the inverse function. These functions are extensively used internally, but are probably of little interest to clients. Subclasses that override one method should probably override the other as well.

HandleAppleEvent

```
void HandleAppleEvent(const AppleEvent& message, AppleEvent& reply,  
    long refCon);
```

`HandleAppleEvent` is called whenever the application receives an Apple event. All responsibility for distributing the Apple event to an object is held by this member function. `HandleAppleEvent` is rarely overridden.

AccessContainedObjects

```
void AccessContainedObjects(DescType desiredClass,  
    const AEDesc& container, DescType containerClass, DescType form,  
    const AEDesc& selectionData, AEDesc& value, long refCon);
```

At times during the resolution of an object specifier, `MAAppleObjects` are asked to return objects contained within them. `AccessContainedObjects` is called when the parsing engine makes that query (in other words, it's the polymorphic counterpart of the OSL's object accessor callback routine). The method is responsible for getting the `MAAppleObject` container, making the appropriate inquiry, and returning the result, properly packed. `AccessContainedObjects` is rarely overridden.

CountObjects

```
long CountObjects(const AEDesc& containerToken,  
    DescType countObjectsOfType);
```

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At times during the resolution of an object specifier, it may be helpful to find out how many of a particular object are contained within a token object. This method is called when the parsing engine makes that query (in other words, it's the polymorphic counterpart of the OSL's count objects callback routine). It's responsible for finding

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the MAppleObject corresponding to the token, making the inquiry of the object, and returning the answer.

CompareObjects

```
Boolean CompareObjects(DescType operation, const AEDesc& obj1,  
    const AEDesc& obj2);
```

At times during the resolution of an object specifier, it may be helpful to compare two objects to determine if some logic relationship (for example, less than, equal to, before, or after) holds between them. CompareObjects is responsible for making the inquiry of the appropriate MAppleObject and returning the result (in other words, it's the polymorphic counterpart of the OSL's compare objects callback routine). The semantics of the operation is *obj1 operation obj2*. So, if the compareOperator parameter were kAEGreaterThan, the semantics of the method call would be *obj1 is greater than obj2*. This method is rarely overridden.

DisposeToken

```
void DisposeToken(AEDesc& unneededToken);
```

DisposeToken is called when the OSL determines that a token is no longer necessary. This commonly occurs during resolution of an object specifier. DisposeToken is responsible for acting appropriately (in other words, it's the polymorphic counterpart of the OSL's object disposal callback routine). For the implementation in TAppleObjectDispatcher, this means the routine checks to see if the object is marked as needing disposal, and deletes the object if necessary.

GetTarget

```
MAppleObject* GetTarget(const AppleEvent& message);
```

GetTarget is responsible for looking at the Apple event and determining which object should receive it. Notably, GetTarget is used by HandleAppleEvent. The TAppleObjectDispatcher implementation sends the Apple event to the default object unless the direct parameter is an object specifier. If the direct parameter is an object specifier, it's resolved to an MAppleObject, which is then sent the Apple event. This method is rarely overridden.

SetTokenObjectDisposal and GetTokenObjectDisposal

```
void SetTokenObjectDisposal(MAppleObject* tokenObject,  
    Boolean needsDisposal);  
Boolean GetTokenObjectDisposal(const MAppleObject* tokenObject);
```

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Any MAppleObject can be marked as needing disposal or not needing it. SetTokenObjectDisposal and
GetTokenObjectDisposal manage the internal representation of the table that keeps track of such
information. You may want to override them both (never do it one at a time) to provide your own
representation.

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ResolveSpecifier

```
MAppleObject* ResolveSpecifier(AEDesc& objectSpecifier);
```

ResolveSpecifier returns the MAppleObject that corresponds to the object specifier passed as an argument. Under most circumstances, you don't need to call this routine since it's called automatically to convert the direct parameter of an Apple event into an MAppleObject. If, however, in the course of handling an Apple event, you find another parameter whose descriptorType is typeObjectSpecifier, you'll probably want to resolve it through this routine. Remember that objects returned from ResolveSpecifier may need to be deleted when the application is done with them. To accomplish this, you may either stuff the object into an AEDesc by calling StuffDescriptor and then call AEDisposeToken, or ask whether the object needs to be deleted by calling GetTokenObjectDisposal and delete it if true is returned.

InstallAppleEventHandler

```
void InstallAppleEventHandler(AEEventClass theClass, AEEventID theID,  
    long refCon);
```

InstallAppleEventHandler is very rarely overridden. It's responsible for registering an Apple event with the Apple Event Manager, notifying the manager that the application handles the Apple event.

GetDispatcher

```
TAppleObjectDispatcher* GetDispatcher();
```

This static member function returns the dispatcher object that's currently installed. It's useful for calling TAppleObjectDispatcher member functions from a global scope.

THE 'AEDT' RESOURCE

The last piece of the UAppleObject puzzle is the 'aedt' resource. The definition of this resource type is in the Types.r file distributed with MPW. Developers familiar with MacApp's use of the 'aedt' resource already know how it works in UAppleObject because UAppleObject uses the same mechanism.

The 'aedt' resource is simply a list of entries describing the Apple events that an application handles. Each entry contains, in order, the event class, the event ID, and a numeric reference constant. The event class and ID describe the Apple event the application supports and the numeric constant is used internally by your application. The constant should be different for each supported Apple event. This allows your application to recognize the kind of Apple event at run time by looking at the refCon passed to DoAppleEvent.

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When installed via the Install method, a TAppleObjectDispatcher object looks at all 'aedt' resources in the application's resource fork, registering all the Apple events in them. Thus, additional Apple event suites can be signified by adding resources

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instead of adding to one resource. For example, the Rez code to define an 'aedt' resource for the four required Apple events is as follows:

```
resource 'aedt' (100) {{  
    'aevt', 'oapp', 1;  
    'aevt', 'odoc', 2;  
    'aevt', 'pdoc', 3;  
    'aevt', 'quit', 4;  
}};
```

When the Open Document Apple event ('aevt', 'odoc') is sent to the application, the refCon value to DoAppleEvent is 2. Since you've assigned a unique numeric constant to each different Apple event, a refCon value of 2 can be passed to DoAppleEvent only when the Apple event is Open Document.

To add the mythical foobar Apple event ('foo ', 'bar ') to the application, mapped to number 5, you may either add a line to the resource described above or add another resource:

```
resource 'aedt' (101) {{  
    'foo ', 'bar ', 5;  
}};
```

EXTENDING CPLUSTESAMPLE

So far this sounds all well and good. The theory behind adding Apple event object support holds together well on paper. The framework, UAppleObject, has been written and works. The only thing left is to put my money where my mouth is and actually use UAppleObject to demonstrate the addition of Apple events to an Apple event-unaware application. The subject of this foray into the Twilight Zone is CPlusTESample in the Sample Code folder on the *Developer CD Series* disc. TESample serves as the basis for adding scripting support for object model classes.

CPlusTESample is attractive for a number of reasons. First, it's a simple application that could support some nontrivial Apple events. Second, it's written in an object-oriented style and contains a decent design from the standpoint of separating the user interface from the engine and internal representation. Finally, it's written in C++, a necessary evil for the use of UAppleObject.

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To prove that CPlusTESample actually had the necessary flexibility to add Apple events, I began by adding font, font size, and style menus to the original sample. Adding these features required little modification to the original framework aside from the addition of methods to existing classes. Thus, I was satisfied that the underlying assumptions and framework could hold the paradigm shift of adding Apple event support.

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In identifying the objects of the program, I chose windows and text blocks as the central object classes. If I were more gutsy, I would have attempted to actually define words and characters. However, the ancient programmer's credo crept in — it was more work than I was willing to do for this example. Further complicating this decision was the fact that CPlusTESample is built on TextEdit. Therefore, the obvious concepts of paragraphs and words translated exceptionally poorly into the internal representation, TEHandles. Characters would have been simpler than either paragraphs or words, but I copped out and left it as an exercise for the reader.

The relationships between classes are very straightforward. Windows are contained by the null object and text blocks are contained by windows. However, since I had a concept of window, it became interesting to define various attributes contained in windows: name, bounding box, and position. So, object model classes were defined for names, bounding boxes, and positions.

Behaviors were similarly straightforward. Text blocks, names, bounding boxes, and positions had protocol for getting their data and setting their data. Thus, an Apple event could change a name or text block or could ask for a position or bounding box.

In the end, six classes were defined to implement the object model classes: TESample, TEDocument, TWindowName, TWindowBounds, TWindowPosition, and TEditText. TESample is the application class and functions as the null object. TEDocument implements the window class and is used as the internal representation of the document and all its data. The remaining four classes are ephemeral classes that refer to a specific TEDocument instance and represent the indicated feature of that instance.

From that point, it was straightforward to write methods overriding MAppleObject to provide the containment, counting, comparison, and behavior dispatching. You can check out CPlusTESample with Apple event support added on the *Developer CD Series* disc.

IMPLEMENTING A CLASS

This section shows how UAppleObject helps you write cleaner code by looking at one of the CPlusTESample classes in detail — TEditText, the text class. User testing revealed the need for a class to represent the text found inside a CPlusTESample window, so I created a TEditText class whose objects are contained within some window class. Additionally, users wanted to retrieve and set the text represented by the text class. The *Apple Event Registry* defines a text class that roughly resembles the text class I wanted to provide in my CPlusTESample extension. Therefore, I decided to use the Registry's description as a basis for my TEditText class.

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TEditText provides object model support for the user's concept of text, indicating that it should inherit
from MAppleObject. TEditText objects don't contain any other

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objects, so there's no need to override the CountContainedObjects or GetContainedObject methods. However, TEditText objects do respond to Apple events. The Registry says that text objects should provide access to the text data itself through the Set Data and Get Data Apple events. Therefore, TEditText should include methods to implement each Apple event and should override DoAppleEvent to dispatch an Apple event to the appropriate method. After taking all this into account, here's what TEditText looks like:

```
class TEditText : public MAppleObject
{
public:
    TEditText(TEHandle itsTE);

    virtual void DoAppleEvent(const AppleEvent& message,
        AppleEvent& reply, long refCon);
    virtual DescType GetAppleClass() const;

    virtual void DoAppleGetData(const AppleEvent& message,
        AppleEvent& reply);
    virtual void DoAppleSetData(const AppleEvent& message,
        AppleEvent& reply);
private:
    TEHandle fTEHandle;
};
```

The constructor is relatively simple to implement. Since CPlusTESample uses TextEdit records internally, it's natural to implement TEditText in terms of TextEdit's TEHandle data structure. Therefore, TEditText keeps the TEHandle to which it refers in the fTEHandle instance variable.

```
TEditText::TEditText(TEHandle itsTE)
{
    fTEHandle = itsTE;
}
```

UAppleObject requires each MAppleObject instance to describe its object model class type through the GetAppleClass method. Since all TEditText objects represent the Registry class denoted by typeText, TEditText's GetAppleClass method is exceptionally straightforward, blindly returning the typeText constant.

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```
DescType TEditText::GetAppleClass() const
{
    return typeText;
}
```

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DoAppleEvent is also straightforward. It looks at the refCon parameter to determine which Apple event-handling method should be invoked. This method represents a large part of the remaining tedium for Apple event coding. Each class is responsible for translating the integer-based Apple event specifier, refCon in this example, into a polymorphic method dispatch such as the invocation of DoAppleSetData or DoAppleGetData. The nice part of this implementation is that subclasses of TEditText won't need to implement DoAppleEvent again if all the subclass needed was the Set Data or Get Data protocol. Instead such a subclass would simply override the DoAppleSetData or DoAppleGetData method and let the C++ method-dispatching mechanisms do the work.

```
void TEditText::DoAppleEvent(const AppleEvent& message,
    AppleEvent& reply, long refCon)
{
    switch (refCon)
    {
        case cSetData:
            this->DoAppleSetData(message, reply);
            break;
        case cGetData:
            this->DoAppleGetData(message, reply);
            break;
        default:
            MAppleObject::DoAppleEvent(message, reply, refCon);
            break;
    }
}
```

DoAppleGetData and DoAppleSetData are the Apple event-handling methods of the TEditText class. To developers familiar with the traditional Apple Event Manager interfaces, these methods are the UAppleObject equivalents of what the Apple Event Manager calls Apple event handlers. Each method follows a general pattern common to most remote procedure call protocols, of which Apple events are an advanced form.

First, the Apple event-handling method reads additional information from the message Apple event. The DoAppleGetData method doesn't happen to need any additional information because the entire meaning of the message is found in the identity of the Apple event itself. However, DoAppleSetData needs one additional piece of information — the text that should be stuffed into the object.

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Next, the handler method calls `GetRequiredParameters`, passing the message Apple event as the sole argument. `GetRequiredParameters` ensures that the handler has retrieved all the information that the Apple event sender has sent. (For a discussion of why this is necessary, see *Inside Macintosh* Volume VI, Chapter 6.)

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Third, the handler method will do whatever is necessary to perform the Apple event and create necessary reply data. The Get Data Apple event requires the TEditText object to fill the reply Apple event with the text it represents. Therefore, the DoAppleGetData method should retrieve the text contained in the TEHandle and pack it into an appropriate Apple event descriptor, putting that descriptor into the reply Apple event. In contrast to Get Data, the Set Data Apple event requires no reply, but does require that the text represented by the TEditText object be changed to reflect the text contained by the message Apple event. Thus, the DoAppleSetData method should contain code that sets the text contained in the object's TEHandle to the text retrieved from the message Apple event.

```
void TEditText::DoAppleGetData(const AppleEvent& message,
    AppleEvent& reply)
{
    // Note: This method uses no additional parameters.

    // Make sure we have all the required parameters.
    GotRequiredParameters(message);

    // Pack the text from the TEHandle into a descriptor.
    CharsHandle theText = TEGetText(fTEHandle);
    AEDesc textDesc;
    HLock((Handle) theText);
    OSErr theErr = AECreatDesc(typeText, (Ptr) *theText,
        GetHandleSize((Handle) theText), &textDesc);

    // Unlock the handle and check the error code, throwing an
    // exception if necessary.
    HUnlock((Handle) theText);
    FailOnError(theErr);

    // Package the reply.
    theErr = AEPutParamDesc(&reply, keyDirectObject, &textDesc);

    // Dispose of the descriptor we created and check the reply from
    // packaging the reply, throwing an exception if necessary.
    OSErr ignoreErr = AEDisposeDesc(&textDesc);
    FailOnError(theErr);
}
```

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```
void TEditText::DoAppleSetData(const AppleEvent& message,  
    AppleEvent& /* reply */)
{
    // Get the text data descriptor from the message Apple event.
    AEDesc textDesc;
```

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```
FailOSErr(AEGetParamDesc(&message, keyAETheData, typeText,
    &textDesc));

// Make sure we have all the required parameters.
GotRequiredParameters(message);

// Use the data in the text descriptor to set the text of TEHandle.
HLock(textDesc.dataHandle);
TESetText(*textDesc.dataHandle, GetHandleSize(textDesc.dataHandle),
    fTEHandle);
HUnlock(textDesc.dataHandle);

// Dispose of the text descriptor we created above.
OSErr ignoreErr = AEDisposeDesc(&textDesc);
}
```

IT'S UP TO YOU

This article set out to reveal the deep significance of Apple events and the object model and to find a strategy for developing an object-oriented framework to take advantage of the Apple event object model design. Along the way, it danced around cognitive theory and discussed how cognitive theory applies to user perception of software. You've seen how object programming resembles such cognitive models to a more-than-trivial degree. And you've seen how those similarities can be leveraged to give workable, programmable models of user concepts within Turbo WhizzyWorks II NT Pro.

You've also seen the difficulties presented by the Apple Event Manager interface. Although Apple event objects and the object model are unarguably tied to user models and user-centric models, the Apple Event Manager is not. The UAppleObject framework presented here works with the object model and the Apple Event Manager to reduce generic user scripting to a tedious but straightforward task.

In the midst of all this detail, don't forget the payoff — providing a mechanism for users to interact with your applications using a level of control and precision previously undreamed of. The rest, as they say, is in your hands.