JADE 6

JADE Development Centre

Packages

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Introduction

This document discusses the use of packages in a JADE system. Since the introduction of subschemas, JADE has allowed a class, along with the properties and methods of a class, to be used through the single inheritance of schemas. Packages are an adjunct to the existing schema structure that allows similar access but in a more controlled manner and without the need for the schema defining the class to be a superschema of the schema using it.

The developer of a package decides what functionality needs to be implemented in an exporting schema and then decides which classes, properties, and methods should be exported in one or more packages. Usually only a small subset of the classes, properties, and methods are exported in the package; only those necessary to expose the functionality required.

Users of the package can then load the exporting schema into their system, usually into an unrelated schema branch, and then import the package into their schema. They then have access to the functionality provided by the package via the classes, properties, and methods exported by the package.

This document covers some of the issues you should consider when both developing and using packages in your JADE applications.

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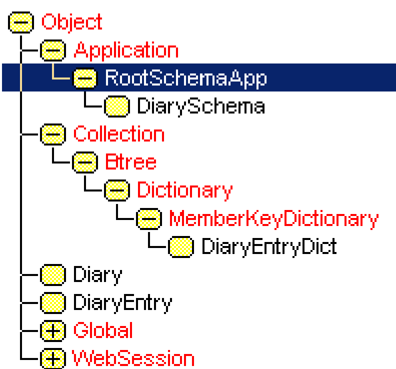
A Simple Diary Package

In order to explain how a package is written and used, let us develop a small example package and work our way through the issues involved in design, implementation, and use. The running example will be a simple diary system that allows the storage of appointments, their retrieval, and display.

We begin by creating a schema that defines the basic classes with their corresponding properties and methods. Note that there is nothing special about a schema that exports a package and it can be tested as a standalone schema before we convert it to a package. The schema we define will be called **DiarySchema** and will be a subschema of the **RootSchema**.



The two major classes will be a **DiaryEntry** class that will represent an appointment and a **Diary** class that will hold a collection of these. Any system can have a number of instances of **Diary**, one for each user for example. The simple system is shown in Figure 1.

The **DiaryEntry** class has attributes **startTime** and **endTime** (both of type **TimeStamp**) for the appointment, along with an attribute **what** (of type **String**) that holds the description of the appointment. The attribute **index** (of type **Integer**) provides a unique number for each appointment within the diary. The manual reference **myDiary** (of type **Diary**) has an inverse **allDiaryEntries** of type **DiaryEntryDict**, a member key dictionary with keys **startTime**, **endTime**, and **index**.

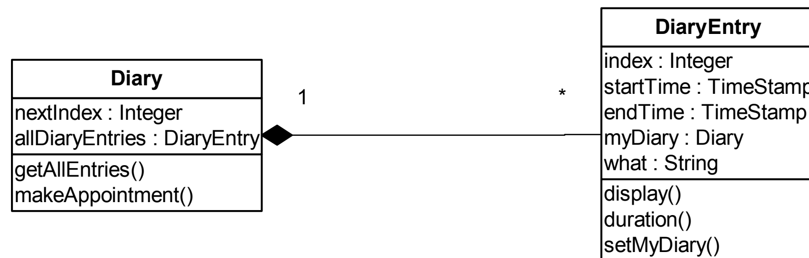


Figure 1 Simple Diary system defined in DiarySchema

The **duration** method returns a **String** (for example, **"30mins"**) showing the timespan of an appointment that is used by the **display** method, which provides further details such as the index, day, time, duration, and description as in:

```
0 Thu 24 Jul 2003 12:30    30mins    Dentist
```

The **Diary** class has a single attribute **nextIndex** (of type **Integer**) that tracks the next highest unique index for a **DiaryEntry** and two methods. The **getAllEntries** method returns a **String** containing all appointments formatted one for each line in the above format.

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The **makeAppointment** method has the following signature.

```
makeAppointment(startTime : TimeStamp;
                durationInMinutes : Integer;
                what : String ) updating;
```

This creates a new **DiaryEntry** object, sets all the attributes of the object and finally sets the **myDiary** reference to self to add the new entry to the diary's **allDiaryEntries** collection.

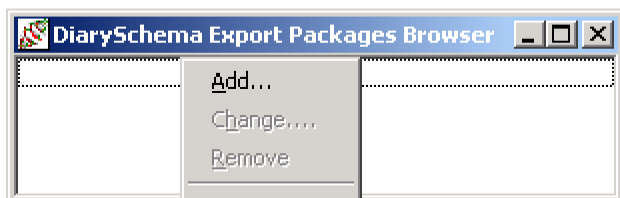
Writing `JadeScript` methods to create a new diary, make new appointments, and write them all out could then test this simple schema.

Having tested our schema thoroughly, we now decide to make it available to other users. Without packages, users would either need to load the classes directly into to their schema or include **DiarySchema** somewhere in their schema hierarchy. If they included the complete schema, they would then be able to use these classes in any subschemas below the **DiarySchema** schema.

However inserting a schema into an existing schema hierarchy, especially one not designed with this in mind, can be problematical. Firstly it is not trivial to insert a new schema, (see FAQ 15063 for the details of how to do this), and the class names used in the schema may already exist in the schema hierarchy below the level at which they wanted to insert it. This would preclude the schema from being inserted, as class names must be unique in a schema branch.

A better solution is to create and export a package from **DiarySchema** and then import it into the schema or schemas where we wish to use it. The first step is to decide which classes, properties, and methods we wish to export and which should remain hidden. In general, it is good practice to only export those parts of the system that are essential for the package to be useful and hide all non-essential details. In our example we have decided to hide the manner in which the collection of **DiaryEntry** objects are stored. The user of the package does not need this information and so we do not need to export the **DiaryEntryDict** class or the **allDiaryEntries** collection property or its inverse **myDiary**. An advantage of not exporting this information is that if we decide at a later date to change the manner in which these are stored, we can do so without any changes to any code that imports the package. Such a change may require a reorganization of any persistent instances of these classes that the user has created. Another property that we do not need to export is the **nextIndex** property on **Diary**. In our case, we decide to export all the methods shown in Figure 1 but we would not export any helper methods these might use.

Having decided on what classes, properties, and methods to export we can now use the package export wizard to define the package. This wizard is available from the **Browse** menu via the **Package** and **Export Browser** menu items. This brings up the DiarySchema Export Packages Browser form and selecting **Add** from the Packages menu displays the series of wizard forms in Figure 2. An alternative to using the export wizard is to use the Export Package Class Browser. This can be opened either by selecting Browse or double-clicking on the package in the DiarySchema Export Packages Browse form, as shown in Figure 3. This view is similar to a standard class browser but limited to the classes, properties, and methods exported in the package.



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Properties and methods can be added to the package by dragging and dropping them between the normal schema class and package class browsers.

The wizard proceeds through the following steps.

Step 1: The package is named **DiaryPackage** and an application from the schema is selected.

Step 2: The classes to be exported, **Diary** and **DiaryEntry**, are selected. Note we have not selected **DiaryEntryDict,** and the system classes, such as **Collection**, are greyed out indicating they cannot be exported. Classes that have been selected to be exported are shown in green.

Step 3: The properties and methods to be exported are selected. Note that the protected members, such as properties **nextIndex**, **allDiaryEntries**, and **myDiary** are not available for export. Also note that we have chosen not to export the method **setMyDiary**, which we wish to be purely internal to **DiarySchema**. (The method **setMyDiary** could not be made protected as it must be visible to the method **makeAppointment** on **Diary**.)

Step 4: Choose lifetimes and default persistence for the exported classes and access modes for their properties. By default these are the same, as they are declared in the exporting schema and can only be made "more restrictive" than their declaration.

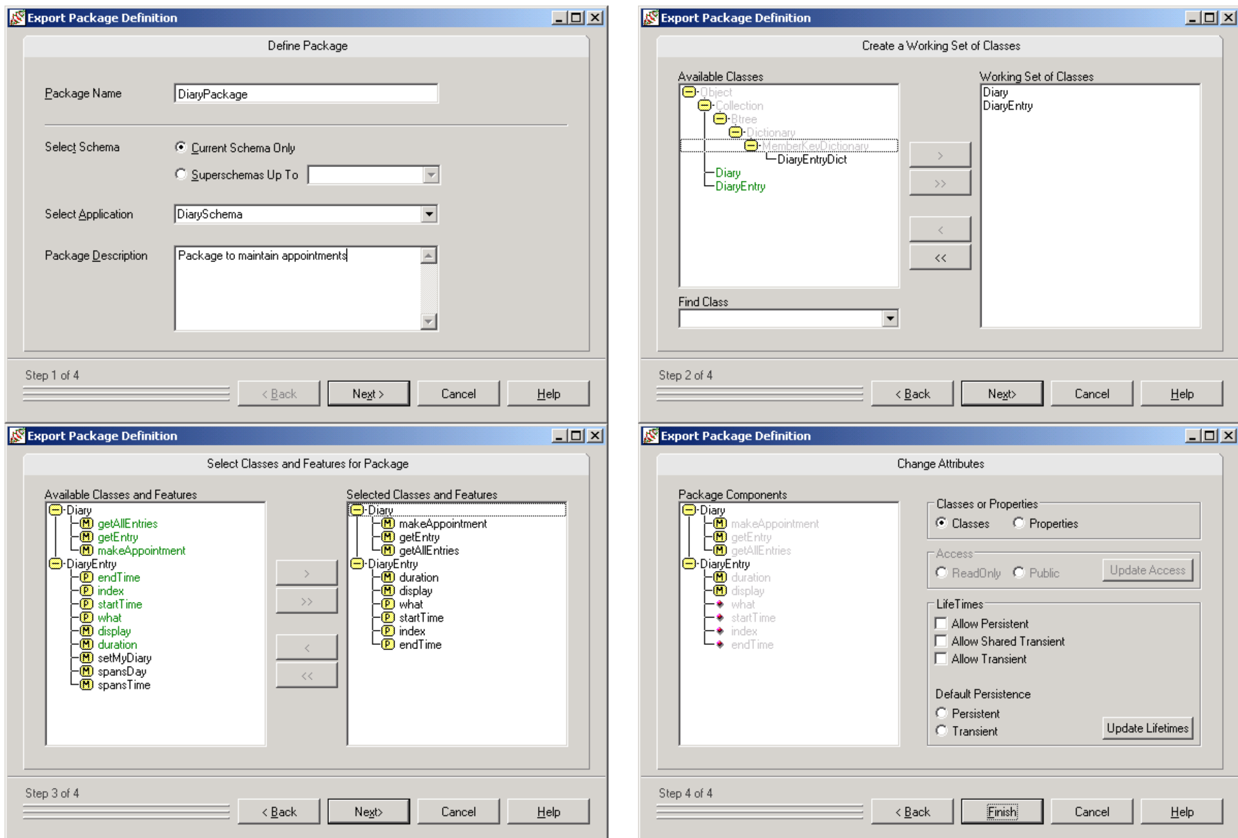

Figure 2 Steps in creating DiaryPackage via the Export Package Wizard

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An alternative to using the export wizard is to use the Export Package Class Browser. This can be opened either by selecting Browse or double-clicking on the package in the DiarySchema Export Packages Browser form as shown in Figure 3.

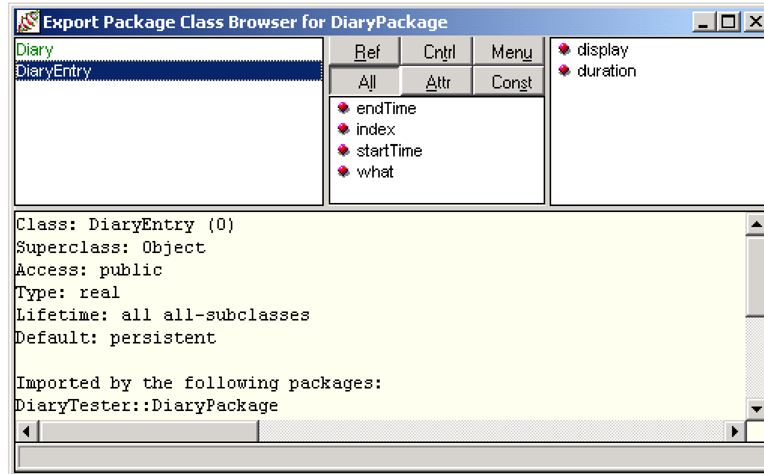


Figure 3 The Export Package Class Browser

This view is similar to a standard class browser but limited to the classes, properties, and methods exported in the package. To add properties and methods, they can be dragged and dropped between the normal schema class and package class browsers.

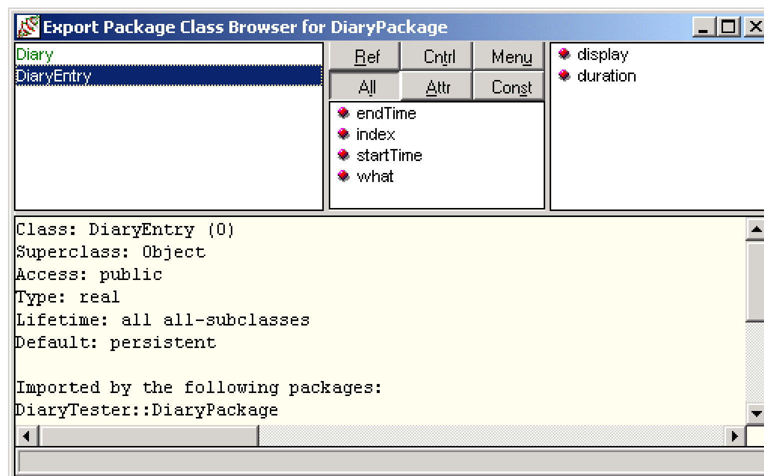
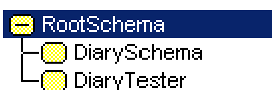


Figure 3 The Export Package Class Browser



Having defined our exporting package, we can now import it into another schema and use it to create and manipulate diaries. The importing schema need not be a subschema of the exporting schema and would normally have only the **RootSchema** as a common ancestor in our example schema **DiaryTester**. We can now import the **DiaryPackage** into this schema using the **Browse** menu via the **Package** and **Import Browser** menu items. This brings up the DiaryTester Import Packages Browser form and selecting **Add** from the **Packages** menu allows us to select which exported packages we wish to import. As can be seen from Figure 4, there is an option to rename the package. This facility is provided in case the name of the package conflicts with another package we have already imported.

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As we will see, it is not a problem if the names of any of the imported classes conflict with classes already defined in the schema or imported from other packages.

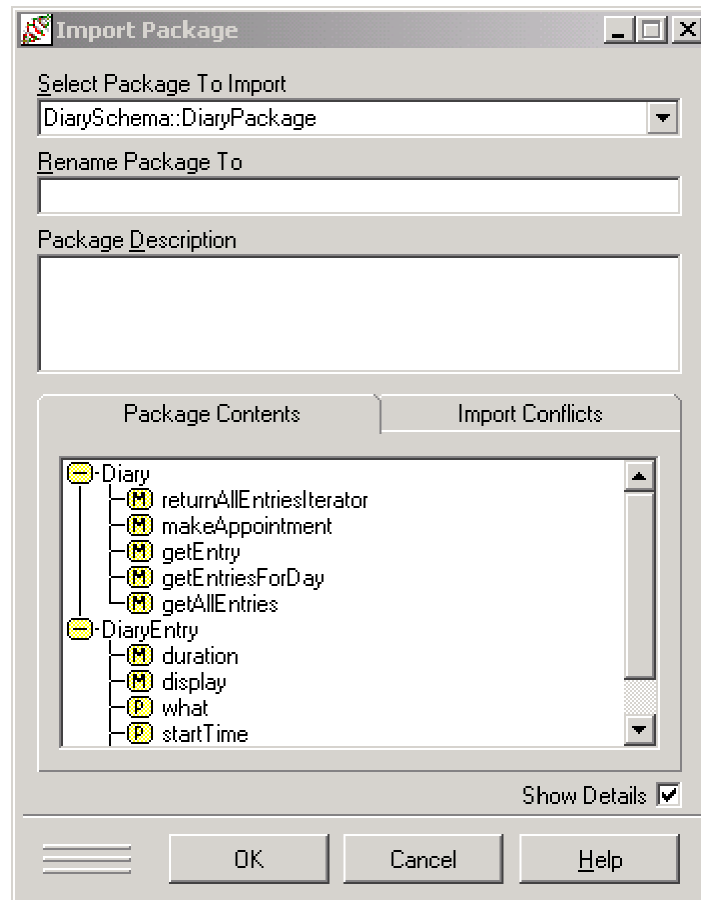

Figure 4 Inserting the DiaryPackage into the DiaryTester schema

Having imported the **DiaryPackage**, opening a normal class browser for the schema **DiaryTester**, as shown in Figure 5, displays the imported classes along with their properties and methods in green. These may not be modified. If the package schema has been encrypted when it was extracted, the source of any exported methods would not be shown in the browser.

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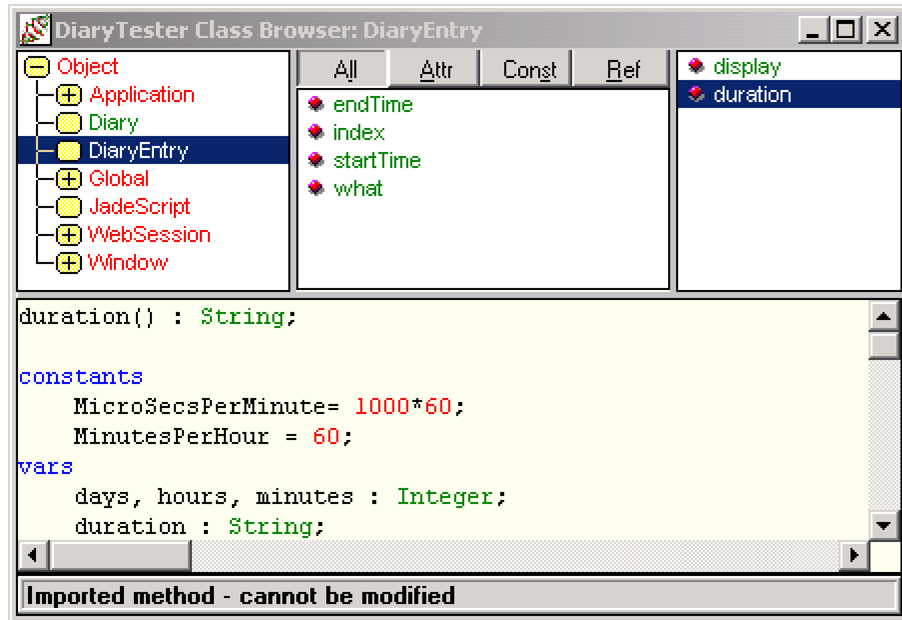

Figure 5 Class browser for DiaryTester schema after importing DiaryPackage

The imported classes and methods can now be used as in the following **JadeScript** method.

```
createDiary();
vars
            diary : DiaryPackage::Diary;
            today : TimeStamp;
begin
            beginTransaction;
            if app.diary = null then
                  create app.diary;
            endif;
            today.setTime('12:30'.Time);
            app.diary.makeAppointment(today, 30, 'Dentist');
            today.setTime('18:00'.Time);
            app.diary.makeAppointment(today, 60, 'Squash');
            write app.diary.getAllEntries;
            commitTransaction;
end;
```

The reference to the imported class **Diary** uses the double colon (`::`) scope operator as in `DiaryPackage::Diary`. If there is no ambiguity as to which class **Diary** represents, as in our schema where there is no local **Diary** class and no other imported **Diary** class, then a simple `Diary` can be used rather than `DiaryPackage::Diary`.

When the method call `app.diary.getAllEntries` is made in this script, a switch is made from the **DiaryTester** schema into the exporting **DiarySchema**. Along with this switch is a change in the environmental context of the process. In particular, there is a switch in the meaning of environmental variables such as **app**, **global**, and **currentSession** to those of the exporting package. This enables the package developer to use references to these in their code. A common use of this will be to access the properties and methods of **app** in the package to save context information.

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To illustrate this switch of context, suppose we add the following method to class **Diary** and exported it in **DiaryPackage**.

```
printAppGlobal();
begin
        write 'App and Global in Diary::printAppGlobal';
        write ' app='&app.getName &
             ' global='&global.getName;
end;
```

If we then ran the following **JadeScript** method in schema **DiaryTester**:

```
showSwitch();
vars
        diary : DiaryPackage::Diary;
begin
        diary := DiaryPackage::Diary.firstInstance;
        write 'App and Global in showSwitch before call';
        write ' app='& app.getName &
             ' global='&global.getName;
        diary.printAppGlobal;
        write 'App and Global in showSwitch after call';
        write ' app=' &app.getName &
             ' global=' &global.getName;
end;
```

then the output would be:

```
App and Global in showSwitch before call
 app=DiaryTester global=GDiaryTester
App and Global in Diary::printAppGlobal
 app=DiarySchema global=GDiarySchema
App and Global in showSwitch after call
 app=DiaryTester global=GdiaryTester
```

Notice that both **app** and **global** have switched from those that apply in the importing schema **DiaryTester** to those that apply in the exporting schema **DiarySchema** while executing the exported method **printAppGlobal**, and then have switched back.

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Scope Rules for Method Calls

Having imported the class **DiaryEntry** along with its associated imported properties and methods we are able to add local methods to the class. These methods can be called from the importing schema and any subschemas, just like normal methods without any schema switch. For example, we could add the following method to the class.

```
weekendEvent() : Boolean;
begin
   // write app.getName();
   if startTime.date.dayOfWeek = 6 or
      startTime.date.dayOfWeek = 7 then
         return true;
   else
         return false;
   endif;
end;
```

This can be called from a **JadeScript** method.

```
testWeekendEvent();
vars
   de : DiaryEntry;
begin
   createDiary;
   de := DiaryEntry.firstInstance;
   write de.weekendEvent;
end;
```

If the commented out **write** statement in the method **weekendEvent** was uncommented, it would yield **DiaryTester**, showing the **app** had not been switched from the schema from which the **JadeScript** was executed.

However, what if we add a local method to an imported class that has the same name as a method that already exists on the class in the exporting schema? Note that the importer of the package may not even know this has happened, as the method with the same name may not have been exported. Adding a local method with the same name is allowed, and the local method does not even have to have the same signature as the method in the exporting schema. For example, although a **display** method is exported on **DiaryEntry**, we could also add a local **display** method with a different implementation, as shown in the following table.

<table>
<tr><td>Exported display method</td><td>Local display method</td></tr>
<tr><td><pre>display(): String;
begin
 return index.String &
  startTime.date.format(" ddd d MMM yyy ") &
  startTime.time.format("hh:mm") &
  Tab & duration() & Tab &
  what & CrLf;
end;</pre></td><td><pre>display(): String;
begin
 return what & Tab & duration() & " at " &
       startTime.time.format("hh:mm") & CrLf;
end;</pre></td></tr>
<tr><td>producing output of the form</td><td>producing output of the form</td></tr>
<tr><td><pre>0 Wed 6 Aug 2003 12:30   30mins   Dentist</pre></td><td><pre>Dentist 30mins at 12:30</pre></td></tr>
</table>

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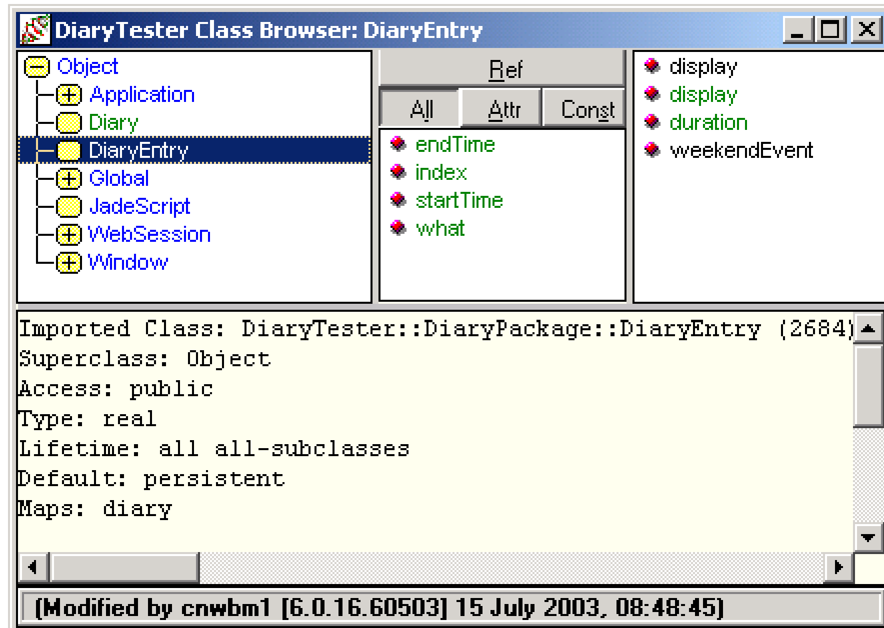
After this, two **display** methods show in the method frame of the class browser for the class **DiaryEntry**: one green for the imported method and one black for the local method. So which **display** method gets called? More precisely, the question should be: which **display** method gets invoked in which context?



The resolution of this is that the most-local definition of the method is called. In particular, this means that when the method is called from within the **DiaryTester** schema, as from a **JadeScript** method for example, the local version is invoked. However, when execution has switched to the exporting schema, for example as a result of invoking the exported method **getAllEntries** on class **Diary** (which invokes **display** to produce the **String** of all appointments), then the **display** method defined within **DiarySchema** (and exported) is used.

NOTE: It is useful to understand why the scope rules are defined in this manner.

The rule that within the exporting package schema the local definition (which may or not be exported) is used protects the developer of the package. The developer knows that the functionality of the package will not be changed and potentially compromised by any user of the package adding local methods to the exported class.

The rule that within the importing schema the local definition is used allows the developer of the importing schema to control how that imported class behaves. For example, it may be that within their schema, all classes must have a method **display** that behaves in a particular manner so that code such as the following will behave correctly.

```
displayAllObjectsInSet(oSet : ObjectSet);
vars
   o : Object;
begin
   foreach o in oSet do
      write o.display;
   endforeach;
end;
```

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Furthermore, suppose we now removed the local **display** method on the imported **DiaryEntry** call and executed the call **de.display** on a **DiaryEntry** object **de**. What output would be expected? It might be surprising that the output would be something like the following:

```
---Diary/2683.7---
```

This is because the **display** method defined on class **Object** in the **DiaryTester** schema has been called. This is regarded as the "most-local definition" because it is defined on a superclass of **DiaryEntry**. Only if no definition was found in the local schema, or inherited from a superschema, would the imported **display** method be called.

However, what if we really wanted to call the imported **display** method rather than the method on **Object**, how can this be done? We can achieve this by defining a local **display** method on **DiaryEntry** with the following form.

```
callImportedDisplayMethod() : String;
begin
   return importMethod display();
end;
```

The keyword `importMethod` tells the compiler that we want the imported **display** method of the current class to be invoked rather than any local **display** method.

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Switching app on Exported Method Call

As noted in a previous section, when a method in another package is called, a switch is made from the current schema into the exporting package schema along with a change in the environmental context of the process. In this section we will see how the resulting switch of **app** enables us to store context information.

In our running **Diary** example we made a decision to hide the manner in which **DiaryEntry** objects were stored. Although a method **getAllEntries** was supplied to return all appointments as a formatted list, this would be inconvenient for users of the package. To extract appointments for a particular day, or the details of a given appointment, the user of the package would need to parse this string.

We decide we wish to provide methods on **Diary** that will allow the user of the package to specify which appointments he or she wants to see and then return them one at a time as **DiaryEntry** objects. To do this, we will add two properties to the **DiaryPackage** class which is the type of the **Application** object exported as part of the package. These properties are **savedDiaryEntries** of type **DiaryEntryArray** (a subclass of **Array** with membership **DiaryEntry**) and **iterator** of type **Iterator**. Neither of these properties or the **DiaryEntryArray** class will be exported, but are available within the package code and can be accessed via **app**.

We can now export methods such as the following on **Diary**.

```
getDayEntriesBegin(day : Date);
// initialise iterator over all diary entries occuring
// on day
vars
  de : DiaryEntry;
begin
  app.savedDiaryEntries.clear;
  foreach de in allDiaryEntries where de.spansDay(day) do
    app.savedDiaryEntries.add(de);
  endforeach;
  app.iterator.reset;
end;

getNextDiaryEntry(de : DiaryEntry output) : Boolean;
// Return the next DiaryEntry object from the
// iterator if any
begin
  if app.iterator.next(de) then
    return true;
  else
    return false;
  endif;
end;
```

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These two properties on **app** will need to be initialized before any importer of the package calls them. When a package is imported into a schema, such as the **DiaryPackage** into the **DiaryTester** schema, when any **app** is run from the importing schema, all packages are initialized. This initialization consists of calling the initialize method for the application, which by default is the method **initialize**. Similarly the finalize method of the application, which by default is the method **finalize**, is called when the application finishes execution. This gives the package designer the opportunity to perform any initialization and finalization required for the package to function correctly. Note that the application might have different initialization and finalization methods defined for when it is run in its own schema. For our package we will add the following methods to the **DiaryPackage** class and use the Define Application form (see Figure 6) to set them as the initial and final methods.

```
initializeDiaryPackage() updating;
// Initialize the Diary package properties on app
begin
  savedDiaryEntries.clear;
  iterator := savedDiaryEntries.createIterator;
end;

finalizeDiaryPackage() updating;
// Finalize the Diary package properties on app
begin
  delete iterator;
end;
```

These can be used in the importing schema such as in the following **JadeScript** testing method:

```
printAllForDay();
vars
  de : DiaryEntry;
  today : Date;
begin
  process.initializePackages;
  app.initialize;
  if app.diary <> null then
    app.diary.getDayEntriesBegin(today);
    while app.diary.getNextDiaryEntry(de) do
      write de.display;
    endwhile;
  endif;
  process.finalizePackages;
end;
```

The initialization and finalization of packages does not occur for **JadeScript** or Workspace methods just as the default **app** is not initialized. This is to ensure these are lightweight operations and also because the default **app** may not be the appropriate application to initialize. The calls to process.**initializePackages** and **app.initialize** at the start, and **process.finalizePackages** at the end, of the above **JadeScript** method force this initialization and finalization to occur.

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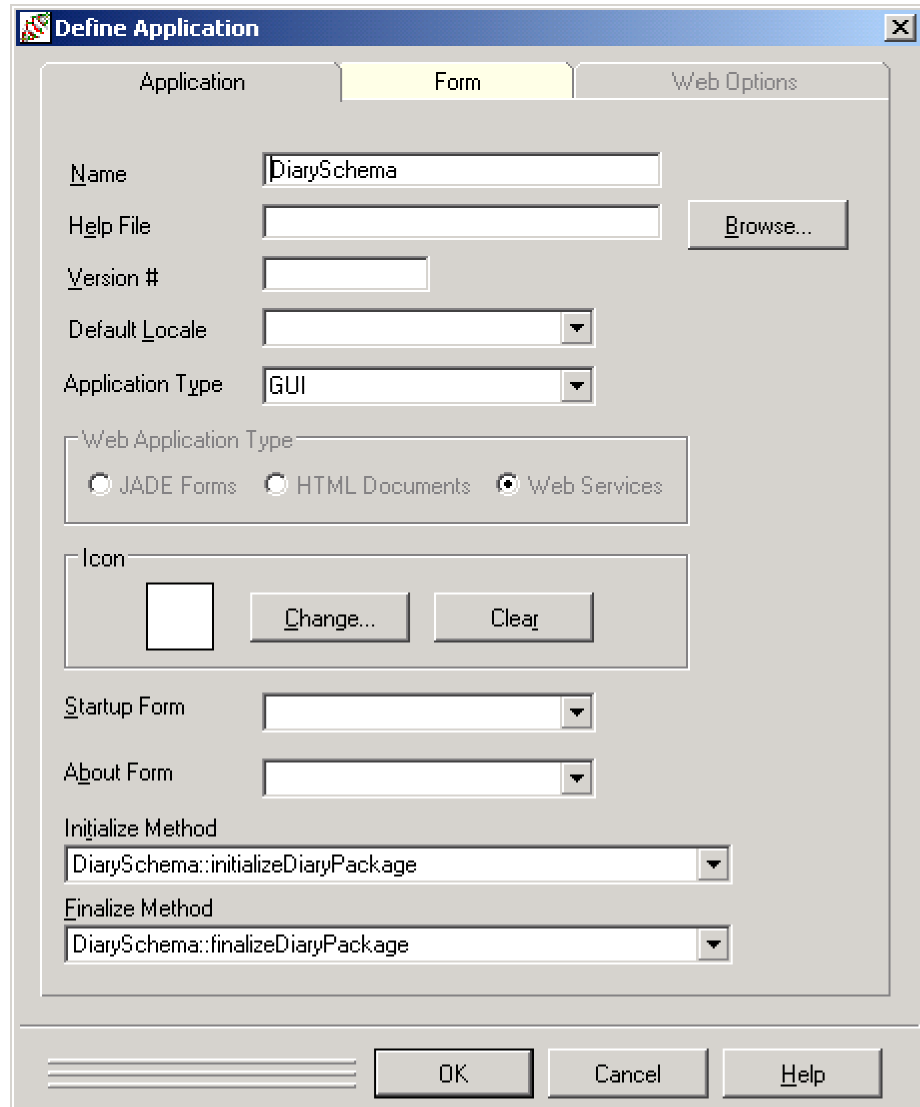

Figure 6 Setting the initial and final methods on the Define Application form

An observant reader will have noted that our design is somewhat limiting as it only allows a single **Diary** to be iterated at a time, and a schema importing our **DiaryPackage** may want to iterate multiple **Diary** objects simultaneously. This could be accommodated by having a collection of transient **DiaryContext** objects on **app**, each of which holds a **Diary** reference along with any context information such as the **iterator** and **savedDiaryEntries** collections. Such a collection could be keyed on a **name** or **id** property added to **Diary**. When a new **Diary** instance is created, the constructor method **create,** defined on the exported **Diary** class, is called. (Note that it is not allowed to add a local constructor or destructor method in the importing schema and all the constructor and destructor methods for the class and superclasses are called in the exporting package schema when an exported class instance is created or deleted.) This would mean the package could create a new transient instance of the **DiaryContext** class when a new **Diary** object was constructed, initialize it and then add it to the collection of those held on the **app**. A similar creation and initialization would occur the first time a new **Diary** instance was seen inside the package, for example, instances that came from **Diary.firstInstance** calls.

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Exporting GUI Subclasses

In the examples above, the classes exported by our packages are all subclasses of **Object**. In this section we will develop a **DateSelector** schema that defines a **DateSelectorPackage** which exports a **DateTableSelector** control that can be added to forms to allow a date to be selected. Having done this, we will import it into our **DiaryTester** schema. This will expose a number of further issues relevant to the use of packages. A class browser for the **DateTableSelector** schema is shown in Figure 7.

The **DateTable** class is a control that is a subclass of **Table** and builds a control that has the form of a table without tabs.

Mon	Tue	Wed	Thu	Fri	Sat	Sun
28	29	30	31	1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31

The control class has a protected property **startOfMonth** of type **Date** that specifies which month is being displayed and is used to determine on which day of the week the month starts and the number of days in the month. The **windowCreated** method, which is called when the control is placed on a form or when a form containing the control is painted, sets the **startOfMonth** property based on the current date. It then calls **fillTable** to fill in the details of the table.

```
windowCreated(cntrl: Control input; persistCntrl: Control)
    updating, clientExecution;
begin
  setStartOfMonth(app.actualTime.date);
  fillTable;
  inheritMethod(cntrl, persistCntrl);
end;
```

The **DateTableSelector** class is a subclass of the **DateTable** class with its own **windowCreated** and **fillTable** methods.

Jul 2003		Aug 2003			Sep 2003	
Mon	Tue	Wed	Thu	Fri	Sat	Sun
28	29	30	31	1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31

The **windowCreated** method has the same code as above but the **fillTable** method has code to add the month tabs to the table. In addition, the class has a property **dateSelected** of type **Date**. Also defined is a method **click** that moves the table to show the next or previous month if the appropriate tab of the table is clicked, or sets the **dateSelected** property to the date selected if one of the days in the month is selected.

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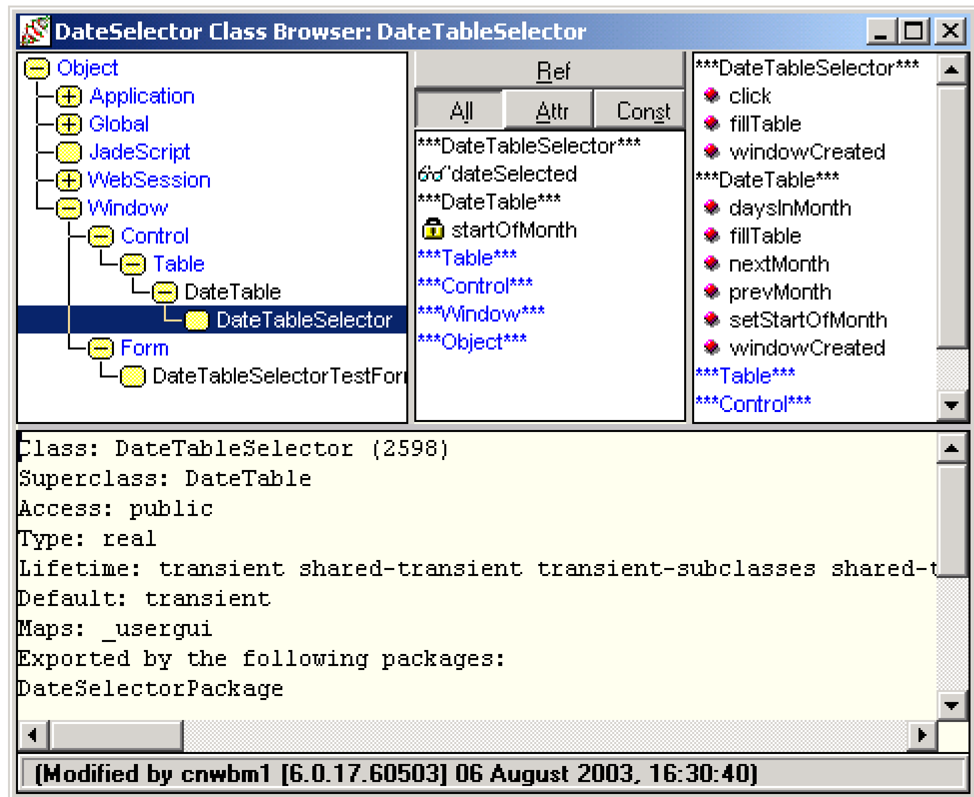

Figure 7 Class Browser for DateSelector schema

The generic **click** method for the **DateTableSelector** control is shown below.

```
click(table: DateTableSelector input) updating,
                                      clientExecution;
vars
  startDay, endDay : Integer;
begin
  dateSelected := null;
  if sheet=1 then
    self.setStartOfMonth(prevMonth(self.startOfMonth));
    fillTable;
    return;
  elseif sheet=3 then
    self.setStartOfMonth(nextMonth(self.startOfMonth));
    fillTable;
    return;
  elseif sheet=2 then
    accessCell(row, column);
    if accessedCell.foreColor = Gray or
       not accessedCell.selected then
      return;
    endif;
    dateSelected.setDate(accessedCell.text.Integer,
        self.startOfMonth.month, self.startOfMonth.year);
  endif;
  inheritMethod(table);
end;
```

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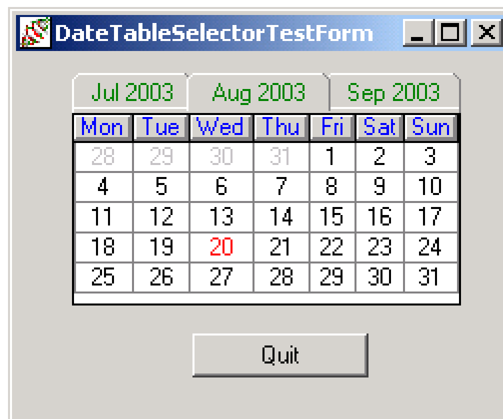
We can test whether this control works correctly within the **DateSelector** schema by creating a form containing the control. We can then check that the table is painted correctly, that it moves to the correct month when the previous and next month tab is clicked, and that the **dateSelected** property of the control is correctly set when a date is clicked.

We now want to export this control as part of a package **DateSelectorPackage** so we must decide which classes and features to expose. Clearly we want to export the **DateTableSelector** class, but there seems to be no compelling reason to export its superclass **DateTable**. As to what features to export, we decide that only the property **dateSelected** needs to be exported, to allow users of the control to determine which date of the control has been clicked.

To test this package, we create a **DateSelectorTester** schema, import **DateSelectorPackage**, and create a **DateTableSeclectorTestForm** with the Painter on which we paint an instance of the imported control.



Opening a class browser for this schema, as shown in Figure 7, shows that the imported **DateTableSelector** control class appears with a superclass of **Table**. The superclass of an imported class is defined to be the superclass of the class in the exporting schema if that superclass is also exported in the *same* package. If that superclass is *not* exported, as in our current case, the superclass of the imported class is the first system class in the superclass hierarchy; in this case the **Table** system class. Note that if we had also exported the **DateTable** class in the **DateSelectorPackage,** it would have been the superclass of **DateTableSelector**. If instead we had exported the **DateTable** class in a completely different package and then imported that into our **DateSelectorTester** schema, both the **DateTable** and **DateTableSelector** classes would have the *same* superclass; namely **Table**.

The consequence of these rules means that when a method is searched for locally on an object of the imported class **DateTableSelector**, it will be searched for locally on the chain of classes **DateTableSelector**, **Table**, **Control**, **Window**, **Object**. If no method of that name is found on that chain, a switch will be made into the exporting schema and the method will be searched for on the chain **DateTableSelector**, **DateTable**, **Table**, **Control**, **Window**, **Object**.

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So, for example, if in the **DateSelectorTester** schema the statement **write dts.display;** is executed, where the variable **dts** is of type **DateTableSelector,** a **display** method would be found within the local heirachy (by default, the one on class **Object**).

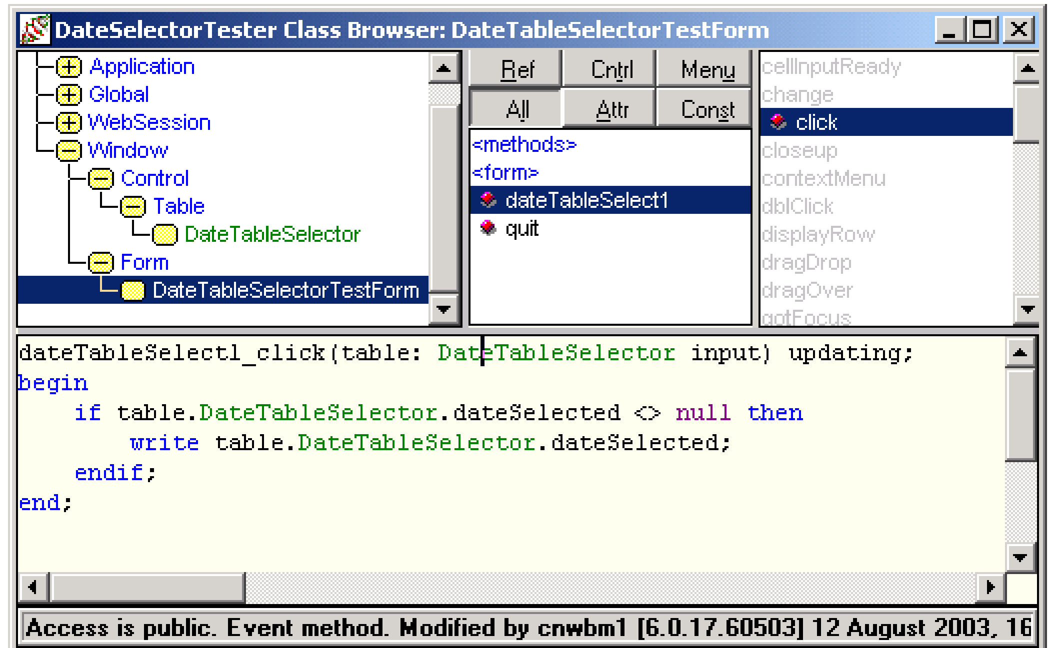

Figure 8 Class browser for DateSelectorTestor schema showing click method

However, there are a number of additional rules that need to be kept in mind when importing classes.

1. Implementing locally any constructor (**create**), destructor (**delete**), or mapping method is not permitted. Thus when the statement **create dts;** is executed, the context is switched to the exporting schema, and all **create** methods on the chain **DateTableSelector**, **DateTable**, **Table**, **Control**, **Window**, **Object** are executed.

2. Event messages also cannot be implemented locally. This includes methods such as **click** and **paint** on GUI classes, and timer and notification handlers such as **timerEvent**, **userNotification**, and **sysNotification**. One reason for this is that such methods would always be found locally as they are defined on system classes, and the *wrong* method would invariably be found. For example, if the **timerEvent** method were searched for locally, a method would always be found locally as there is an abstract method by that name on the class **Object**. Another reason for only looking for the method in the exporting schema is to avoid compromising the behaviour defined by the package implementation.

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Although we cannot override the generic **click** method defined on the exported **DateTableSelector** class, we are able to define a **dateTableSelect1_click** method to the local instance of the control **dateTableSelect1** that appeared as a result of painting an instance of the control on the form. As can be seen from the definition of this method in Figure 8, this method writes the date held in the property **dateSelected** if the user clicked on a date in the table. This method would be called when the generic **click** method calls **inheritMethod(table)** near the end of the method.

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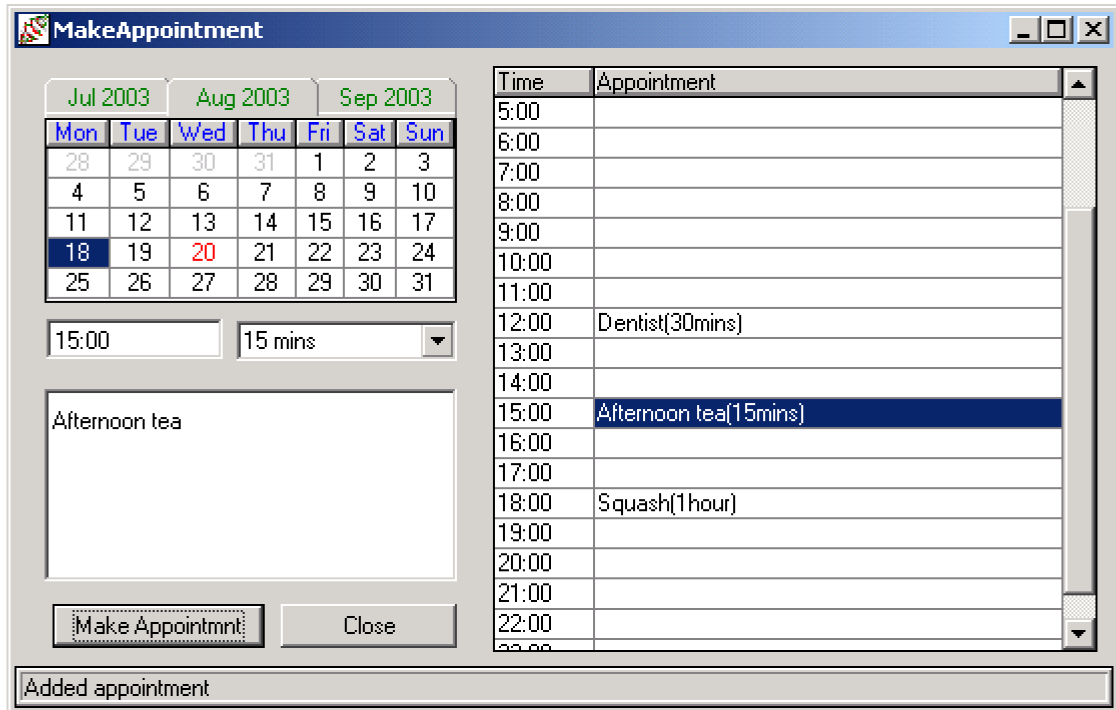
Combined Appointment Book Example

Having written both a **DateSelectorPackage** and a **DiaryPackage**, we can use both of these to implement a simple appointment book by extending our **DiaryTester** schema. After importing both we can see in Figure 9 that the class browser shows all three imported classes. We now add a MakeAppointment form.



The form includes a date selector control that has a **dateTableSelect2_click** method. This method is called when the user selects a day on the calendar. This calls a local method **fillTableForDay** that uses imported methods **getDayEntriesBegin** and **getNextDiaryEntry** on **Diary** to obtain the **DiaryEntry** instances from the **Diary** and fill the right-hand side table with the appointments. Appointments can be added to the **Diary** by filling in the details and using the imported method **makeAppointment** on **Diary**.

Although this is a rather rudimentary appointment book, it would be straightforward to extend it to provide the additional facilites such as multiple diaries, importing or exporting appointments, and the other features normally provided by appointment books.

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By using packages to develop the basic facilities rather than building them all into a single schema, we can clearly separate the implementation of the basic facilities from their use and they can easily be imported into other schemas that require diary or date selecting facilities. Note that it would be easy to package up the final schema to produce an **AppointmentBookPackage** which could also be imported into schemas to provide a complete appointment book facility.

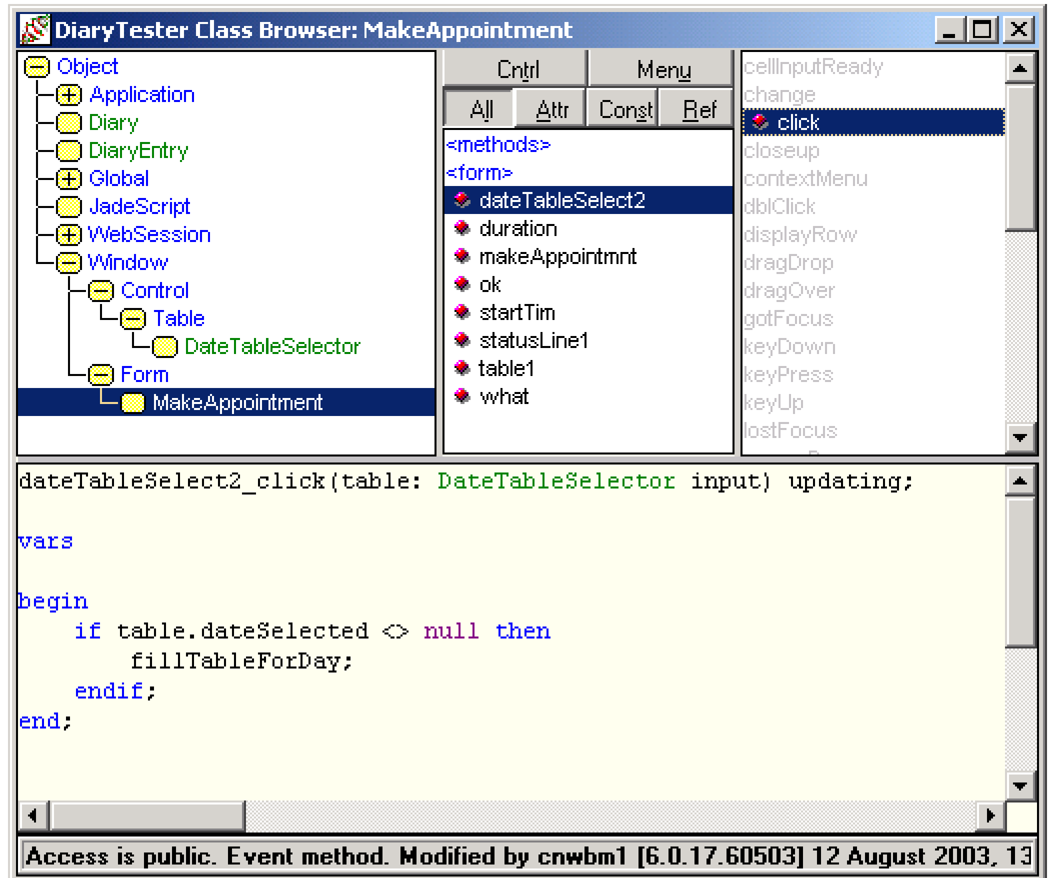

Figure 9 Class browser for DiaryTester schema after importing both packages

How do Packages Call User Methods?

Finally we address the question of how a package can cause actions to occur back in the schema that imported them. This topic covers issues that are more advanced than those covered earlier in this paper and can be skipped on an initial reading.

A feature common to many appointment book systems is the ability to associate an alarm with an appointment so that it is activated when the starting time is reached. This alarm may send an e-mail, bring up an alert form, or perform some other such action to alert the user of the impending appointment. How might this feature be added to our example system?

We shall create a new **CronSchema** schema that exports a **CronPackage** with classes **Scheduler** and **ScheduledEvent** as shown in

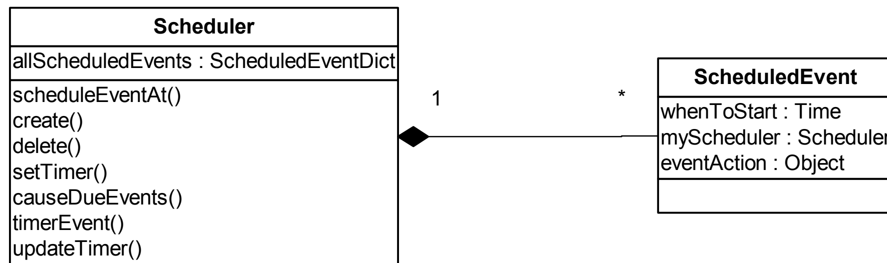

Figure 10. The method **scheduleEventAt** on the root transient class **Scheduler** will be used to add new events.

```
scheduleEventAt(when : Time; action : Object) updating;
vars
  se : ScheduledEvent;
begin
  create se transient;
  se.whenToStart := when;
  se.eventAction := action;
  se.myScheduler := self;
  updateTimer;
end;
```

The **when** parameter specifies the time we wish the event to occur and the **action** will be used to specify what is to occur. The method creates a new **ScheduledEvent** transient object, initializes the **whenToStart** and **eventAction** attributes, before setting the reference **myScheduler**. This will add it to the **allScheduledEvents** collection, (which is a queue sorted in ascending time order), before calling **updateTimer**.

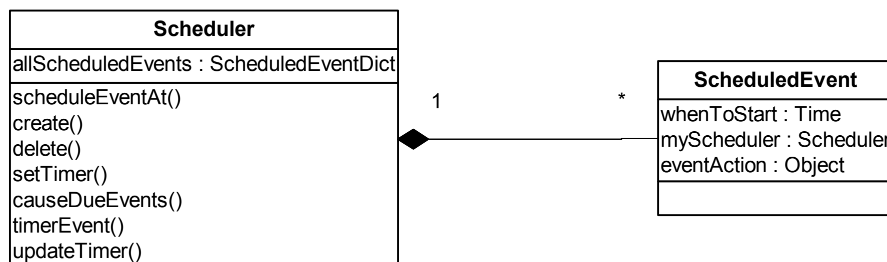

Figure 10 Scheduled event system defined in Cron schema

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The **updateTime** method is shown below. It begins by calling **causeDueEvents** to start any events that are due to run. It then checks if a timer is set to fire when the first event in the queue is scheduled and if there is none, calls **setTimer** to arm a timer by calling **beginTimer**.

```
updateTimer();
// Check that the timer will fire for the first event in
// the queue and if not then cancel existing timer and
// start another
vars
  se : ScheduledEvent;
  option : Integer;
  timeLeft :  Integer;
begin
  causeDueEvents;
  se := allScheduledEvents.first;
  if se = null then
    return;
  endif;
  if getTimerStatus(0, option, timeLeft) then
    // already a timer, check it corresponds to time of se
    if se.whenToStart - app.actualTime.time > timeLeft then
      return;
    endif;
  endif;
  // cancel current timer and start again
  endTimer(0);
  setTimer;
end;
```

When the timer fires, it calls the **timerEvent** method, which in turn calls **causeDueEvents** to start any due events and then **setTimer** to rearm the timer.

How can the **causeDueEvents** method cause events to happen in the schema that called the package? It cannot call a method in that schema as it will have no knowledge of such methods. It does have access to the **eventAction** object that was passed and saved when the event was initially scheduled but does not know what type it is.

The approach we will take will be to use **notifications**. This approach will allow the actions to take place in the importing schema with the correct context and also allow **CronPackage** to be imported into multiple schemas because it does not need to know anything about the type of the **eventAction** object. As the designer of the package, we must decide on a receiver for the notifications. In this design we will choose the user **app** for this object. The notification will be registered in the constructor of the **Scheduler** and has the form:

```
create() updating;
begin
  process.getProcessApp.beginNotification(process,
                             Cron_Event_Type, 0, 0);
end;
```

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This registers the notification on the object **process.getProcessApp**, which is the main process **Application** object, (that is the **app** in the importing schema) with **process** being the notification target object on which the notification is invoked. The destructor terminates the notification by calling **endNotification**. As can be seen in the code for **causeDueEvents** below, the notification is caused by the call to **process.causeEvent** which will cause the method **userNotification** on the importing schemas application class to be invoked, passing it the saved **eventAction** object.

```
causeDueEvents();
// called when timer fires. Inspect all the events at the
// start of the queue and call all those due
vars
  se : ScheduledEvent;
begin
  foreach se in allScheduledEvents do
    if se.whenToStart > app.actualTime.time then
      return;
    endif;
    // cause event passing eventAction as action to perform
    if se.eventAction <> null then
      process.causeEvent(Cron_Event_Type, true,
                         se.eventAction);
      se.myScheduler := null;
      delete se;
    endif;
  endforeach;
end;
```

The **CronPackage** will only export the **Scheduler** class and expose the **scheduleEventAt** method, hiding all of the complications of how events are queued, the setting of timers, and the way events are caused to occur.

A schema **CronTester** that imports **CronPackage** can use it by adding a **userNotification** method to the application **CronTester** class such as the following:

```
userNotification(eventType: Integer; theObject: Object;
                eventTag: Integer; userInfo: Any) updating;
begin
  if not userInfo.isKindOf(Method) then
    write 'Error...method expected';
    return;
  endif;
  sendMsg(userInfo.Method.name);
end;
```

It can then create a transient instance of **CronPackage::Scheduler** and schedule an event at a particular time by code such as the following:

```
scheduler.scheduleEventAt(app.actualTime.time + 5000,
                          CronTester::eventOne);
```

This will result in the **userNotification** method being called in five seconds which will in turn call the method **eventOne** defined on the application class **CronTester**.

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Summary

In this paper we have seen how packages extend the existing schema structure to allow access to the functionality provided without the need for the schema to be among the superschemas. The package developer can decide which classes, and which features of those classes, should be exposed by exporting just those classes and features. This allows access to the functionality of the package in a controlled manner. The user of the package can then import the package and need only be concerned with the exposed interfaces in a type-safe manner, without being exposed to irrelevant implementation detail.

The paper gives concrete examples of how packages can be developed and used by developing a simple appointment book system. Some of the design decisions made were made to expose new and pertinent features of packages, possibly at the expense of efficiency or simplicity. However the developed system could be extended to form the basis of a realistic appointment book system.

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