How to Write an AIPS++ Application

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Contents

1 Purpose

This document describes how to provide AIPS++ functionality at various levels. It is intended to be read by applications programmers. For sections up and including to 6, only good knowledge of glish programming is required. Sections after and including 7 require good knowledge of C++ programming.

2 Introduction

This document describes how an applications programmer can create an application. The term "application" is used loosely to mean any type of computation that is directly invoked by the user. There is a large dynamic range of functionality which is encompassed by this definition: a few lines of Glish script at one end of the spectrum, a very complicated GUI which coordinates activities taking place in many C++ clients at the other.

Writing a few lines of Glish script, such as a throwaway Glish function, is covered in the Glish manual and Glish tutorial.

It is possible to write a fully fledged application solely in Glish. It is reasonably easy to do and can be made easier by using a standard format or idiom, called the *glish closure* form. This enables the programmer to get most of the benefits of objects, and gives the user a standard type of interface to work with. We prefer that you write in this form if possible. It is described further in section 4.

If your application must interact with C++ code then you will probably have to write in the *distributed object* form. The following steps are required:

1. Create C++ distributed objects (DO). This is the compiled code that actually carries out the computation.
2. Bind those DO's to Glish proxy object so users can invoke them directly. This level is the "programming astronomer" level, i.e. used for *ad hoc* calculations or scripts my moderate to advanced users. Proxy objects are the glish "objects" that users directly manipulate.
3. Attach the DO to the *parameters* mechanism so that it is usable by more naive users.

This is described in section 7.

Note that running applications from the Unix command line is not yet supported. This is only because it has not been judged to be high enough priority. Lobby us if you feel this is a mistake.

Both of these forms of applications can be usefully augmented by a GUI. However, GUI development is outside the scope of this paper. The other two forms should be adequately documented here. We solicit feedback on areas that you feel are inadequately documented. We are also very interested in cases where you feel the system produces too little (or too much) diagnostic information to the users, or where you feel the diagnostic messages produced by the system are incomprehensible.

3 General Interface Considerations

Before we get into the nitty-gritty of how to construct an application of either form, a few words on the interface you provide for the user are in order.

3.1 Simple interfaces

While programmers will use the interfaces you provide (real applications can be coded entirely in Glish), the primary audience is *users*. This means that your interfaces should emphasize simplicity, at least until there is a demand for a more capable and complicated interface.

Some of the issues we'd like you to consider are:

- Try to keep the total number of member functions down. Provide only one method of obtaining some result, not multiple methods optimized for slightly different purposes.
- Trade simplicity for runtime efficiency. Slow operations can always be moved into C++.
- Use existing objects as much as possible. Be sparing with the use of trivial functions that simply relay methods from one object to another.
- Do not use Glish defaulted arguments to simulate overloading. One function should perform one operation. For example, do not have a constructor function that can both attach an image to an existing file, or create one from a shape and a description. Use different names for these two purposes.
- Prefer Glish tool methods to global functions if there are a number of related functions, even if they do not need to share any state.
- If you are a programmer, ask a user for his opinion about your interface. If you are a user, ask another user for his opinion.
- Documentation can cure many sins of interface design. Examples can save otherwise poor or skimpy documentation.

3.2 Naming conventions

All user-invokable Glish functions must be entirely in lower case. Internal functions and variables may be in mixed case if you prefer. Generally words are run together, however you may use underscores to separate words if you are imitating a glish builtin (e.g. writing an `is_image()` function that apes the builtin Glish `is_record()` et al.)[1]. However, generally we prefer `openfile()` to `open_file()`. Generally, names should err on the side of being somewhat longer and unambiguous, however commonly typed names can be short since repetition will ensure that they are not obscure.

If you only expect one object of a type to *typically* exist the class name should be be a verb – `imager`. If you expect that more than one object of that class might be active at once it should be be a noun – `table`. In Glish, the most common common constuctor function should have the name of the class: `mytable := table("file")`.

[1] You do not need to make such `is*` functions unless you have need of them personally.

Class names will be normally be singular when the object refers to a single entity (`image`, `table`). Occasionally it might be plural if the object refers to a collection of some tye `units`.

You should try to use the same function names in your Glish objects that are used in other Glish objects that perform similar operations. This reduces the number of names that a user has to remember. You might break this rule however if the argument lists have to be very different in the two classes. Some names you should be aware of:

open Attach the object to a file.

summary Summarize the state of the object (e.g. for an image, one would provide the size, coordinate information, and the like).

display Start a GUI browser/editor for the object.

delete Destroy/remove/... the current object. The Glish proxy object should disable itself so that it is no longer usable .

shape Return the length of each "axis" in the object.

length Return the total number of values in the object.

Sometimes you expect that the user will only need a single instance of a particular kind of object inside Glish, and you premake it for them so they don't have to. Call these objects `defaulttype`, for example, `defaultlogger`, and make then (and the constructor) const to avoid somone inadvertently changing them.

3.3 Other considerations

Generally you should not have "null" objects. A created object should always be fully manipulatable.

4 Writing an Application Solely in Glish

Applications in glish are conveniently written in the glish closure object idiom. In this idiom, the object contains both publically and privately visible functions and data. A full blown example is the imager module in the synthesis package. A simpler example is to be seen in the example of a tableplotter tool (this does not actually exist in the package):

```
pragma include once
include "table.g";
include "plotter.g";

# Constructor for a table plotter object
const tableplotter:=function(tableplotterlogger=defaultlogger,         #1
              tableplotterplotter=defaultplotter) {

# Private functions and data
```

```
#---------------------------------------------------------------------------
  private:=[=];                                                          #2

# Convenience function: is this vector one-dimensional?               #3
  const private.is_1d:=function(vec) { ... };

# Public functions
#---------------------------------------------------------------------------

  public:=[=];

# Is this object valid?                                               #4
  const public.ok:=function() {
    if(is_boolean(private.table)) fail "need to settable";               #5
    if(!private.is_1d(private.x.data)) fail "x is not a 1d vector";
    if(!private.is_1d(private.y.data)) fail "y is not a 1d vector";
    return T;
  }

# Delete this object: no-op for this implementation                   #6
  const public.delete:=function() {return T;}

# set and verify x
  const public.setx:=function(x, fn=F) {
    wider private;
    private.x.col:=x;
    private.x.data:=private.table.getcol(x);
    if(is_function(fn)) private.x.data:=fn(private.x.data);
    if(!private.is_1d(private.x.data)) fail paste("not a 1-d vector:",
      private.x.data::shape);
    return T;
  }

# set and verify y
  const public.sety:=function(y, fn=F) { ... }

# return a record containing the actual x and y to be plotted
  const public.getxy:=function() { ... }

# set and verify the table
  const public.settable:=function(tablename) { ... }

# autoscale
  const public.auto:=function() { ... }

# plot x vs y
  const public.plot:=function() { ... }

# return a reference to the public functions and data
  return ref public;
```

```
# end of the definition of tableplotter
  }

# Global Demonstration function
  const tableplotterdemo:=function() { ... }

# Global Test
  const tableplottertest:=function() { ... }

# Make standardly named tableplotter                                  #7
const defaulttableplotter:=tableplotter();

# Make standard abbreviation
const tp:=ref defaulttableplotter;

# log to the standard logger                                          #8
defaultlogger.log('', 'NORMAL', "defaulttableplotter ready for use", 'tableplotter');
defaultlogger.log('', 'NORMAL', "tp is short for defaulttableplotter", 'tableplotter');

} # include guard
```

An example of the use of this object is given below in section 6. Some comments on this code:

1. Pass in resources that the user might wish to change.
2. The basic trick of a closure object is that the public data and functions are attached to a record that is the returned value of the defining function (or constructor). The private functions are declared as part of a record (private) that is not visible externally.
3. Define convenient but private functions as belonging to private.
4. Provide a public method `ok()` that checks the status of the object. This returns either T if ok, or a fail if not ok. You should check the returned value of any method that you use.
5. For error checking and notification, use the fail mechanism. Be sure to check the returned values from other glish functions to determine if a fail has occurred. If so, propagate it upwards by returning it. Careful and disciplined use of fails is essential to writing robust glish code.

   Here is a simple example: the first function uses fail as an alternate return if the table does not exist. The second function therefore has to check for fail type and relay it. Of course, if the return is relayed directly then there is no need for any such checking. Similarly, fail as an input to another function guarantees a fail return some forms of checking can be omitted.

   ```
   tablefromname:=function(tablename)
     {
       if(!tableexist(tablename)) fail "table does not exist";
       return tableopen(tablename);
     }

   vs:=function(vsname)
     {
       public:=[=];
   ```

```
    result:=tablefromname(vs);
    if(is_fail(result)) return result;
    public.table:=result;
    return ref table;
  }
```

6. All important attributes of real classes can be simulated using the closure object idiom except for destructors. This means that you have to provide *and document* a method (conventionally called done) that deactivates the object (*e.g.* deletes any open objects). This has to be used before the object is destroyed by Glish by, for example, going out of scope. Please provide this even if it does nothing for your implementation. If the implementation changes it may be needed in the future. As a corollary, be careful to use the delete method of any object, *e.g.* table, that you use.

7. Since only one of these objects is probably present at any one time, we call it a tableplotter. The standard name for the default such object is thus defaulttableplotter. Since this is rather long-winded, we provide a standard abbrievation tp.

8. If you are creating something, tell the user.

5 Writing a GUI for Your Application

5.1 Application Framework

A GUI can help users effectively use an application. Application GUI's have many levels, from simple and straight forward, to complex and time consuming to write. Many books have been written about GUI programming, for a good overall introduction to GUI programming please look at Cooper's book, **"About Face: the Essentials of User Intergace Design, IDG Books World Wide, 1995"**. For for look and feel issues, refer to the Motif style guide, **"OSF/Motif Style Guide, Revision 1.2, Prentice Hall, 1993?"**. Several of us in the AIPS++ group use Welch's book, **"Practicle Programming in Tcl and Tk, Prentice Hall, 1995"**, about TCL/TK programming for nuts and bolts of GUI programming.

Glish/Tk uses much of Tcl/Tk philosophy so books about Tcl/Tk programming may provide some insight. Unfortunately Glish/Tk doesn't have all the functionality of Tcl/Tk, so if you need a feature and it isn't currently supported ask.

5.1.1 Philosophy

All AIPS++ applications that have a GUI should present a similar look and feel to the user. A "similar look and feel" means:

1. Provide a consistent menubar. A typical menubar consists of File, Options, and Help menus. Other traditional menus include Edit and View. Other application specific menus may be added.

2. Use a consistent naming/action convention for buttons. The standard button labels are:

   - OK, do the requested action, dismiss the window;
   - Apply, do the requested action but don't dismiss the window;
   - Reset, reset all the values in the window to thier previous values, don't dismiss the window; and
   - Cancel, dismiss the window and do nothing.

   If it's clear to the user use it, in our printer example rather than labeling a button OK, it makes more sense to use the label Print.

3. Call the same file/data chooser window, so the user is not confronted with a customized load/save window for every application.
4. Use the same message window layout to display informational content. Message windows are either blocking, program waits for a user response, or non-blocking, program continues. Choose to block only when user input is necessary for continued program execution.
5. Message windows which require the user to choose one of several options should block the application until the user has made a choice.
6. Provide an informational title for every window.
7. Use either a progress bar or a status message at the footer of the window to let the user know something is going on, or happened.

Figure 1 shows the major parts of a command action window. Please try and follow the motif style guide when assembling the parts in the "work area". There are several standard utilities/building

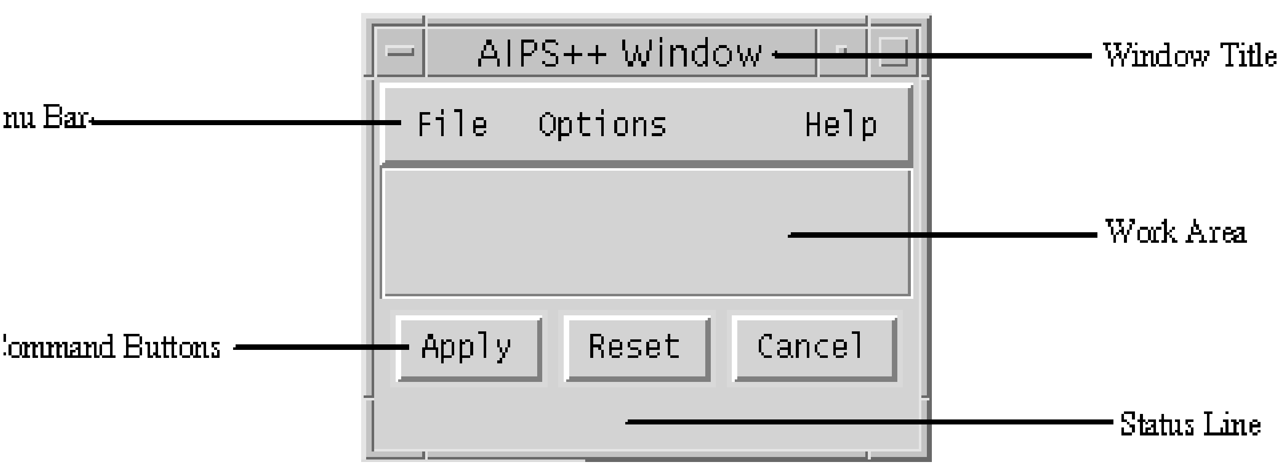

Figure 1: The basic AIPS++ gui window.

blocks for constructing a consistent interface,

- guiframework,
- filechooser,

- datachooser,
- choices, and
- miscellaneous functions found in guiutils.

Please use them rather than rolling your own.

If you're doing a simple load and go interface we hope to provide a "load-and-go utility" that will let you specify a few glish records and the produce a standard GUI.

5.1.2 An example

The example comes from printer.g. It illustrates setting up a help menu and action buttons for the printer objects gui. The event handler self.printfunction follows the code snippet (it preceedes it in the actual code).

```
public.gui := function(files="", remove=F, landscape=F)
{
    wider self
    files := as_string(files)
    self.files := files
    self.remove := remove

    if (landscape) {
        self.mode := 'l'
    }

    if (!have_gui()) {
      self.logger.log('',
       'SEVERE', 'Does not appear to be connected to a windowing system',
                      'printer::gui')
        fail 'Does not appear to be connected to a windowing system'
    }
```

This code initializes some "self" variables and checks if the user is running in a windowing system, if not it the function exits with a fail. If you write gui functions, you should check whether a user is capable of running your function.

```
    # set the help menu
    helpmenu := [=];
    helpmenu::text := 'Help';
    helpmenu.print := [=];
    helpmenu.print.text := 'Printing';
    helpmenu.print.action := function(){help('Refman:utility.printer')};
    helpmenu.reference := [=];
    helpmenu.reference.text := 'Reference';
```

```
helpmenu.reference.action := function(){help('Refman')};
helpmenu.about := [=];
helpmenu.about.text := 'About AIPS++...';
helpmenu.about.action := about;

# set the action buttons
actions := [=];
actions.print := [=];
actions.print.text := 'Print';
actions.dismiss := [=];
actions.dismiss.text := 'Dismiss';

# application's window
self.gf      := guiframework('AIPS++ Printer control', F, helpmenu,
                              actions)

# add the handlers
self.gf.addactionhandler('dismiss', self.gf.dismiss)
self.gf.addactionhandler('print', self.printfunction);
```

This section of code, sets up the help menu, action buttons, creates the frame work and adds the action handlers. It's important that the action handlers be defined before you add them, otherwise you handler will not be called.

```
# Get the workframe and do everything else the same.
self.wholeframe := self.gf.getworkframe()

#
self.filesframe      := frame(self.wholeframe, side='left')
self.fileslabel      := label(self.filesframe, 'Files:',width=20)
self.filesentry      := entry(self.filesframe)
if (length(files) > 0) {
   send self.filesentry->insert(files)
   send self.filesentry->disabled(T)
} else {
   whenever self.filesentry->return do {
     self.files := $value
   }
}

# Remove
self.removeframe     := frame(self.wholeframe, side='left')
self.removelabel     := label(self.removeframe,
                          'Remove after printing:',width=20)
self.removebutton    := button(self.removeframe, 'Yes',
                                type='check')

send self.removebutton->state(self.remove)
```

```
        whenever self.removebutton->press do {
          self.remove := request $agent->state()
        }

        ... Lots of stuff removed ...

        return T
    }
```

After grabbing the work area frame, we go about the job of adding frames, buttons and labels to the frame work.

```
    self.printfunction := function(){
           wider self;
           wider public;
           self.files := request self.filesentry->get()
           self.printer_name := request self.printerentry->get()
           if (length(self.files) == 0 ||
              (length(self.files)==1 && self.files[1] == '')) {
              self.logger.note('Not printing any files',
                                  origin='printer::gui')
              a := infowindow('No files to print', 'AIPS++ Printer Control');
            } else {
              public.print(self.files, self.remove)
              self.gf.dismiss();
           }
        }
```

Here's the call back used to print the file(s). The call back need not be a "self" function. An alternative form would be:

```
        self.gf.addactionhandler('print', function(){
           wider self;
           wider public;
           self.files := request self.filesentry->get()
           self.printer_name := request self.printerentry->get()
           if (length(self.files) == 0 ||
              (length(self.files)==1 && self.files[1] == '')) {
              self.logger.note('Not printing any files',
                                  origin='printer::gui')
              a := infowindow('No files to print', 'AIPS++ Printer Control');
            } else {
              public.print(self.files, self.remove)
              self.gf.dismiss();
           }
        });
```

How you add the callbacks is a matter of style. For complicated functions it is better to define your functions first rather than define them in the argument to addactionhandler. For short functions, a few lines, in-lining the function call works just as well.

5.2 Input Forms

For the programmer who want's a GUI but doesn't need the fine control of GUI components offered by glishTk, we have two stylized input forms available. The programmer specifies a *Screen Input Record* and invokes either a `gui.inputform` or `gui.tabform`. The following three examples are from inputframe.g. The first example builds a stand-alone form, the second uses a parent frame, and the third shows a pseudo-tab form.

The *Screen Input Record* is defined as

title	text in the window title
label	text in the window
actions	(a.label a.function)record of functions
layout	ignored for now
data	record of datums
progress	T or F (Shows a progress bar, not implemented)

Each member of a *data record* is an *input-field* and has the following members

label	Description of datum field
type	one of the following: string, float, double long, integer, file, table, time, date, or text - string with more than oneline of text
required	boolean, T if required for processing
hint	one of: check, radio, list, menu
enums	vector of allowed values
multiple	boolean for allowing multiple choices of enums
range.min	minimum value
range.max	maximum value
default	default value
verify	function to verify input
mask	display mask (not implemented)
help.url	a URL to drive a web browser (not implemented)
help.text	text for help of this field (not implemented)

If the type is file or table, a file or data-chooser is launched.

If the type is an integer with a range of values then it will appear as a slider.

If there are more than four enums, a list box will be used otherwise check or radio buttons will be used. Hints will be honored, so you may have more than four check or radio buttons by specifying the hint record.

In the first example(output form shown in Figure 2), the programmer supplies the parent frame gui.inputform Each of the controls are illustrated.

```
gui.testframe := function()
```

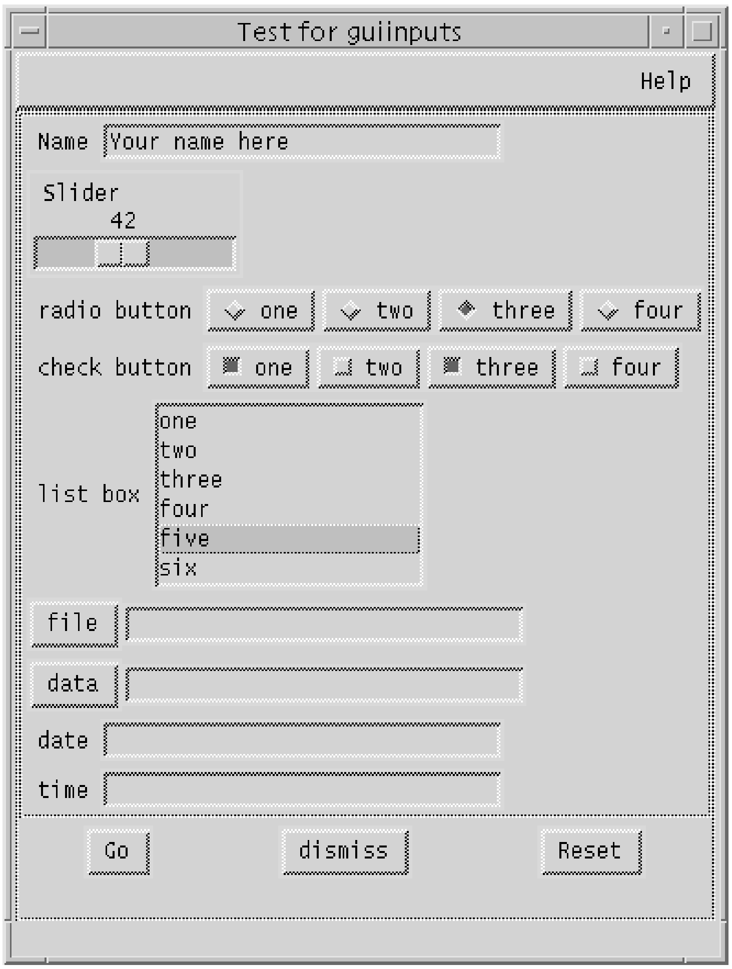

Figure 2: An example of the AIPS++ Input Form window.

```
{  global gui;
#
   wreck := [=];
   wreck.actions := [=];
   wreck.data := [=];
#
   wreck.title := 'Test of input form';
#
   wreck.data.name := [=];
   wreck.data.name.label := 'Name';
   wreck.data.name.type := 'string';
   wreck.data.name.default := 'Your name here'
#
   wreck.data.slider := [=];
   wreck.data.slider.label := 'Slider';
   wreck.data.slider.type := 'int';
   wreck.data.slider.range.min := 1;
```

```
   wreck.data.slider.range.max := 100;
   wreck.data.slider.default := 42;
#
   wreck.data.rb := [=];
   wreck.data.rb.label := 'radio button';
   wreck.data.rb.type := 'string';
   wreck.data.rb.default := "three"
   wreck.data.rb.enums := "one two three four";
#
   wreck.data.cb := [=];
   wreck.data.cb.label := 'check button';
   wreck.data.cb.hint := 'check';
   wreck.data.cb.type := 'string';
   wreck.data.cb.default := "one three"
   wreck.data.cb.enums := "one two three four";
#
   wreck.data.lb := [=];
   wreck.data.lb.label := 'list box';
   wreck.data.lb.type := 'string';
   wreck.data.lb.multiple := F;
   wreck.data.lb.enums := "one two three four five six seven";
   wreck.data.lb.default := "five";
#
   wreck.data.file := [=];
   wreck.data.file.label := 'file';
   wreck.data.file.type := 'file';

 #
   wreck.data.data := [=];
   wreck.data.data.label := 'data';
   wreck.data.data.type := 'table';
#
   wreck.data.date := [=];
   wreck.data.date.label := 'date';
   wreck.data.date.type := 'date';
#
   wreck.data.time := [=];
   wreck.data.time.label := 'time';
   wreck.data.time.type := 'time';
#
   wreck.actions.go := [=];
   wreck.actions.go.label := 'Go';
   wreck.actions.go.function := function(data){print data;}
#
   wreck.actions.dismiss := [=];
   wreck.actions.dismiss.text := 'Dismiss';
#
   hmenu := [=];
   hmenu::text := 'Help';
   hmenu.about := [=];
   hmenu.about.text := 'About';
```

```
   hmenu.about.relief := 'flat';
   hmenu.about.action := about;

   gf := guiframework('Test for guiinputs', F, hmenu, F)
   fgf := gui.inputform(wreck, parent=gf.getworkframe());
   fgf.addactionhandler('dismiss', gf.dismiss);
}
```

The second example is nearly identical to the first except that gui.inputform creates the parent window and default help menu.

```
gui.testinputs := function()
{  global gui;

#
   wreck := [=];
   wreck.actions := [=];
   wreck.data := [=];
#
   wreck.title := 'Test of input form';
#
   wreck.data.name := [=];
   wreck.data.name.label := 'Name';
   wreck.data.name.type := 'string';
   wreck.data.name.default := 'Your name here'
#
...lots of lines deleted for brevity (all similar to gui.testframe)...
#
   wreck.actions.go := [=];
   wreck.actions.go.label := 'Go';
   wreck.actions.go.function := function(data){print data;}
#
   fgf := gui.inputform(wreck);
}
```

The third example, Figure 3, shows a *tab-input form*. *Tab-input forms* are most useful when you have an object with several methods.

```
gui.testtab := function()
{  global gui;
#
   wreck := [=];

   wreck1 := [=];
   wreck2 := [=];
   wreck3 := [=];
   wreck4 := [=];
   wreck5 := [=];
   wreck6 := [=];
```

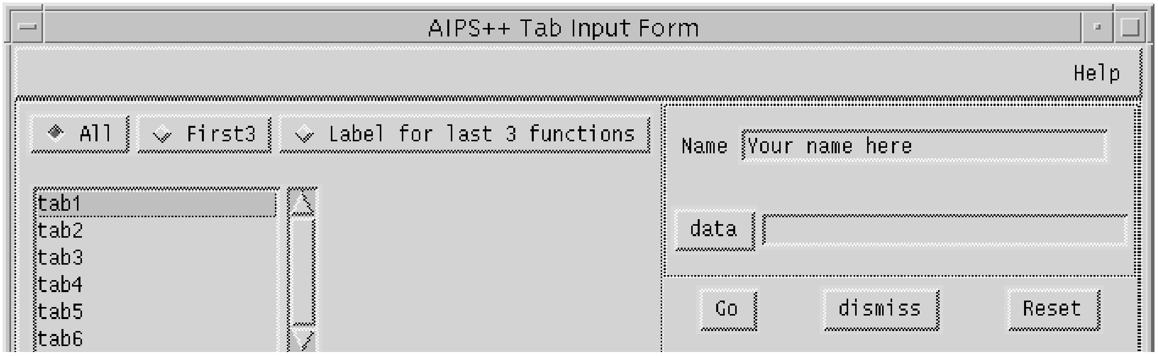

Figure 3: An example of the AIPS++ Tab-Input Form window.

```
   wreck1.actions := [=];
   wreck1.data := [=];
   wreck1.title := 'Test of tab form, pane 1';
#
   wreck2.actions := [=];
   wreck2.data := [=];
   wreck2.title := 'Test of tab form, pane 2';
#
   wreck3.actions := [=];
   wreck3.data := [=];
   wreck3.title := 'Test of tab form, pane 3';
#
   wreck4.actions := [=];
   wreck4.data := [=];
   wreck4.title := 'Test of tab form, pane 4';
#
   wreck5.actions := [=];
   wreck5.data := [=];
   wreck5.title := 'Test of tab form, pane 5';
#
   wreck6.actions := [=];
   wreck6.data := [=];
   wreck6.title := 'Test of tab form, pane 6';
#
   wreck1.data.name := [=];
   wreck1.data.name.label := 'Name';
   wreck1.data.name.type := 'string';
   wreck1.data.name.default := 'Your name here'
#
   wreck2.data.slider := [=];
   wreck2.data.slider.label := 'Slider';
   wreck2.data.slider.type := 'int';

   wreck2.data.slider.range.min := 1;
   wreck2.data.slider.range.max := 100;
```

```
   wreck2.data.slider.default := 42;
#
   wreck3.data.rb := [=];
   wreck3.data.rb.label := 'radio button';
   wreck3.data.rb.type := 'string';
   wreck3.data.rb.default := "three"
   wreck3.data.rb.enums := "one two three four";
#
   wreck4.data.cb := [=];
   wreck4.data.cb.label := 'check button';
   wreck4.data.cb.hint := 'check';
   wreck4.data.cb.type := 'string';
   wreck4.data.cb.default := "one three"
   wreck4.data.cb.enums := "one two three four";
#
   wreck5.data.lb := [=];
   wreck5.data.lb.label := 'list box';
   wreck5.data.lb.type := 'string';
   wreck5.data.lb.multiple := F;
   wreck5.data.lb.enums := "one two three four five six seven";
   wreck5.data.lb.default := "five";
#
   wreck6.data.file := [=];
   wreck6.data.file.label := 'file';
   wreck6.data.file.type := 'file';
#
   wreck1.data.data := [=];
   wreck1.data.data.label := 'data';
   wreck1.data.data.type := 'table';
#
   wreck2.data.date := [=];
   wreck2.data.date.label := 'date';
   wreck2.data.date.type := 'date';
#
   wreck3.data.time := [=];
   wreck3.data.time.label := 'time';
   wreck3.data.time.type := 'time';
#
   wreck1.actions.go := [=];
   wreck1.actions.go.label := 'Go';
   wreck1.actions.go.function := function(data){print data;}
#
   wreck1.actions.dismiss := [=];
   wreck1.actions.dismiss.text := 'Dismiss';
#
   wreck2.actions.go := [=];
   wreck2.actions.go.label := 'Go';
   wreck2.actions.go.function := function(data){print data;}
#
   wreck2.actions.dismiss := [=];
   wreck2.actions.dismiss.text := 'Dismiss';
```

```
#
   wreck3.actions.go := [=];
   wreck3.actions.go.label := 'Go';
   wreck3.actions.go.function := function(data){print data;}
#
   wreck3.actions.dismiss := [=];
   wreck3.actions.dismiss.text := 'Dismiss';
#
   wreck4.actions.go := [=];
   wreck4.actions.go.label := 'Go';
   wreck4.actions.go.function := function(data){print data;}
#
   wreck4.actions.dismiss := [=];
   wreck4.actions.dismiss.text := 'Dismiss';
#
   wreck5.actions.go := [=];
   wreck5.actions.go.label := 'Go';
   wreck5.actions.go.function := function(data){print data;}
#
   wreck5.actions.dismiss := [=];
   wreck5.actions.dismiss.text := 'Dismiss';
#
   wreck6.actions.go := [=];
   wreck6.actions.go.label := 'Go';
   wreck6.actions.go.function := function(data){print data;}
#
   wreck6.actions.dismiss := [=];
   wreck6.actions.dismiss.text := 'Dismiss';
#
   wreck.tab1 := wreck1;
   wreck.tab2 := wreck2;
   wreck.tab3 := wreck3;
   wreck.tab4 := wreck4;
   wreck.tab5 := wreck5;
   wreck.tab6 := wreck6;
#   wreck::disallow := "tab3 tab4";
#   wreck::show := "tab3";
   wreck::categories := [=];
   wreck::categories.All := T;
   wreck::categories.First3 := "tab1 tab2 tab3";
   wreck::categories.Last3 := "tab4 tab5 tab6";
   wreck::categories.Last3::label := 'Label for last 3 functions'

   fgf := gui.tabform(wreck, tabcount=3, side='left');
   fgf.dismisshandler('dismiss')
}
```

6 Documenting Your Application

6.1 Background

Good documentation is vital for the success of code contributed to AIPS++. Without documentation, your code will be neglected. In AIPS++, user documentation is written in latex using a set of special purpose macros. These are defined in aips2help.sty. The example for the tableplotter is worth studying.

If at all possible, provide a global function for demonstration that illustrates how the application is to be used. Place the demo function inside the `.g` file that contains the application code. Try to make the demonstration as self-contained as possible without compromising the demonstration. Here is the demo function for tableplotter:

```
const tableplotterdemo:=function() {
  localtp:=tableplotter();
  col1:=tablecreatescalarcoldesc("N",0);
  col2:=tablecreatescalarcoldesc("N^2",0);
  td := tablecreatedesc (col1, col2);

  tb := table('squares', td, 100);
  tb.putcol("N", 1:100);
  tb.putcol("N^2", (1:100)^2);

  print localtp.settable(tb);
  print localtp.setx("N")
  print localtp.sety("N^2");
  print localtp.auto();
  localtp.x.label:="N";
  localtp.y.label:="N**2";
  localtp.title:="Squares";
  print localtp.show();
  print localtp.getxy();
  print localtp.plot();
  print tb.delete();
  print shell('rm -r squares');
}
```

Note that it is self-contained, constructing a table specially for the demonstration. Note also that all public functions are invoked. Remember that a good demonstration can often help a user penetrate the fog of confusing or inadequate documentation.

To support writting user based help for AIPS++ in LaTeX, we have developed an aips2help.sty file for generating stylistically proper documentation. While it is not necessary for you to write the documentation using the aips2help.sty we urge you to use it. If you use the aips2help.sty and the help templates, it will be possible to parse the help input files and provide non-html-on-line help.

User help (for scripts and stand-alone commands) is written at three levels:

- Module,
- Object, and
- Function/Method.

There are three template .help files (template-module-help, template-object-help, template-function-help) that should be used. By convention the files end in .help. Each template file contains several items that ought to be in the documentation.

To see what your .help file will look like in the "AIPS++ User Reference Manual"you need to run `help2tex` on your .help file. `Help2tex` translates the .help file into a vanilla LaTeX used in the "AIPS++ User Reference Manual". You may run `latex2e` or `latex2html` on your .help file without running it through `help2tex`, but the output will be different from what appears in the "AIPS++ User Reference Manual".

6.2 aips2help.sty

Aips2help.sty defines several environments and commands.

6.2.1 aips2help.sty Environments

(Note: Preface the environment with `\begin{ahenvironment}` and end the environment block with `\end{ahenvironment}`.)

{ahpackage}{one}{two} Defines a package. The first argument is the package name the second argument is a short description of the package. Packages contain usually just modules.

{ahmodule}{one}{two} Defines a module. The first argument is the module name the second argument is a short description of the module. Module may contain tools as well as functions.

{ahtool}{one}{two} Defines a tool. The first argument is the tool name the second argument is a short description of the tool. Tools may contain function/methods.

{ahfunction}{one}{two} Defines a function/method. The first argument is the function/method name, the second argument is a short description of the function/method. If used in an ahtool environment the function is a "member function" of that tool. If defined outside of an ahtool environment but inside an ahmodule environment it is a global function.

{ahconstructor}{one}{two} Defines a constructor. The first argument is the constructor name, the second argument is a short description of the constructor. Only makes sense if used inside an ahobject environment.

{ahaipsrc} Identifies what aipsrc variables may be used. Use `\ahaddarg` to identify the aipsrc variables.

{ahdata} Identify public data for an object. Use `\ahdatum` to identify public data members.

{ahrecord} Identify members of a record. Use `\ahdatum` to identify record members.

{ahdescription} Specifies a more complete desciption of module, object, or function/method.

{ahargs} Defines an argument list, use `\ahaddarg` to identify the arguments.

{ahexample} Present an example of how to use the module, object, function/method here. You will need to enclose the actual example text inside of a `\begin{verbatim}` `\end{verbatim}` block.

{ahcomments} Put comments about the example in this environment.

{ahseealso} Put links to other things of interest here. Use the `\ahlink` command to specify what else to look at.

6.2.2 aips2help.sty Commands

\ahinclude{one} Use this command to identify any files to include. Most useful with glish.

\ahkeyword{one}{two} Use this command to index a keyword with the module, object, or function/method. The second argument should be left blank. The \ahkeyword are used to index the user documentation. While any word(s) maybe used for keywords we suggest using nouns only.

\ahfuncs This command will print a list of functions with their corresponding short descriptions. Used in the ahmodule or ahobject environments. If used within the ahobject/ahtool environment it will print a list of member functions and constructors for the tool. If used with in the ahmodule environment it will print the global functions for that module.

\ahmethods This command will print a list of methods with their corresponding short descriptions. Used in the ahobject environment.

\ahobjs This command will print a list of objects with their corresponding short descriptions. Used in the ahmethod environment.

\ahlink{one}{two} This command specifies a link between the text specified in argument one and a label specified in argument two. A typical use of this command would be to link to another tool or function of the reference manual. The reference manual uses the following scheme for labeling tools and functions,

- modulename:toolname
- modulename:toolname.constructor (.constructor identifies it as a constructor)
- modulename:toolname.function (.function identifies it as a global function)
- modulename:functionname
- modulename:toolname.functionname

An example for the calc constructor is

```
\ahlink{calc the constructor}{images:image.calc.constructor}

for the global calc function
\ahlink{calc the function}{images:image.calc.function}
```

Used inside the ahseealso environment.

ahaddarg[in — out — inout {one}{two}{three}{four}] This command is used inside the ahargs environment. The name is specfied in argument one, a description is specified in argument two, the default value is specified in argument three, and the allowed values are specfied in argument four.

ahaddarg{one}{two}{three}{four} This command is used inside the ahrecord and ahdata environments. The name is specfied in argument one, a description is specified in argument two, the default value is specified in argument three, and the allowed values are specfied in argument four. The optional argument specified in [] identifies the argument as either an input, output, or input and output.

ahreturns{one} This command tells what is returned from a function or method.

6.3 Modules

After writing module documentation you need to include the module in the existing package .help file adding your module with the line:

```
\input{mypackage.help}
```

This example of module documentation comes from code/trial/apps/table/table.help.

```
\begin{ahmodule}{table}{Glish interface to table system}

\ahinclude{"table.g"}

\begin{ahdescription}
table allows creation of table objects inside Glish. The resulting
objects can be operated on in various ways:
\begin{itemize}
\item Creation of new tables,
\item Opening, deletion, cloning, copying of existing tables,
\item Set and put of table information strings,
\item Get and put of table cells, columns and keywords,
\item Iteration by subtables,
\item Access via table rows,
\item Browsing of tables,
\item Printing of a summary of a table,
\end{itemize}
In addition this module contains a number of global functions
related to tables.
\end{ahdescription}

\begin{ahexample}
\begin{verbatim}
include "table.g"
vis:=table("3C273XC1.MS", readonly=T);
vis.summary();
```

```
uvw:=vis.getcol("UVW");
spw:=table("3C273XC1.MS/SPECTRAL_WINDOW", readonly=T);
freq:=spw.getcell("REFERENCE_FREQUENCY", 1);
uvw*:=(1.420E9/freq);
vis.putcol("UVW", uvw);
vis.close();

\end{verbatim}


\end{ahexample}
\begin{ahseealso}
\ahlink{tablerow}{tablerow.label}
\ahlink{tableiterator}{tableiterator.label}
\end{ahseealso}

\ahobjs{}
\ahfuncs{}

.... Lots of stuff deleted

\end{ahmodule}
```

6.4 Object

This example of object documentation comes from code/trial/apps/table/table.help.

```
\begin{ahobject}{table}{table object}

\begin{ahconstructor}{table}{Construct table object}
\begin{ahargs}
\ahaddarg{tablename}{Name of table on disk}{F}{Bool}
\ahaddarg{tabledesc}{Table descriptor}{F}{Bool}
\ahaddarg{nrow}{Number of rows}{0}{Int}
\ahaddarg{readonly}{Open Read-only?}{F}{Bool}
\ahaddarg{ack}{Acknowledge creations, etc}{T}{Bool}
\ahaddarg{tablehandler}{Table handler to be used}{gtable}{Any tableserver}
\ahaddarg{tablelogger}{logger to be used}{logger}{Any logger object}
\ahreturns{object}
\end{ahargs}

\ahfuncs{}

\begin{ahexample}
\begin{verbatim}
table1:=table("3C273XC1.MS");
table2:=table("3C273XC1.new.MS", table1.getdesc());

\end{verbatim}
```

```
\end{ahexample}
\begin{ahcomments}
The first line opens an existing table 3C273XC1.MS, the second creates another
table using the table description of the first table, but no rows are written.
\end{ahcomments}
\end{ahconstructor}

\begin{ahfunction}{ok}{Is the table object ok?}
\ahreturns{Bool}
\end{ahfunction}

....Lots of stuff deleted....

\end{ahobject}
```

6.5 Function/Method

A function belongs to a module, if a function is defined inside an object it is considered a method of that object. This example of function documentation comes from code/trial/apps/table/table.help.

```
\begin{ahfunction}{tablecommand}{Execute a tablecommand}
\begin{ahargs}
\ahaddarg{comm}{Command string}{}{Any valid table command}
\end{ahargs}
\begin{ahexample}
\begin{verbatim}
print tablecommand('SELECT FROM table.in WHERE column1*column2$>$10 ORDERBY
column1 GIVING table.out');


\end{verbatim}


\end{ahexample}
\ahreturns{Bool}

\begin{ahcomments}
The grammar for the command string is SQL-like and is defined
in TableGram.l and explained in Tables.h.
Between SELECT and FROM you can give some column names (separated by
commas). Then the output table will contain those columns only.
If no column names are given, all columns will be selected.
E.g.:   SELECT column1, column2,column3 FROM table.in GIVING table.out

The WHERE part (like column1*column2$>$10) contains an arbitrary expression.
Functions (like sin, max, ceil) are supported. Only scalar columns
(or keywords) can be used in the expression. Complex numbers must
be given as, for example, 3.4+4i (similar to glish).
With some extra syntax (not explained here) it is even possible
to use keywords from other tables in the expression.
```

```
Rows obeying the WHERE expression will be selected.

Sorting can be done with the ORDERBY clause. You can give there any
number of (scalar) columns separated by commas. You can use a mix of
ascending (is default) and descending.
E.g.:   ORDERBY column1 DESC, column2, column3 ASC, column4 DESC

The GIVING clause defines the output table containing the
requested rows and columns. It can be used as any other table.

Each part (column selection, expression, sorting, giving) is optional.
\end{ahcomments}
\end{ahfunction}
```

6.6 Help System Details

Where do we put help files? Put them where the code is. All help files should end in a .help extension. Also, if you use any encapsilated postscript files, put them in that directory too. If you are adding a new object or module, you will have to update the appropriate .help file for the module or project. Currently we have the following project files, aips.help, synthesis.help and nrao.help. All are found in trial/scripts. Module files are likely to be scattered through out the code tree (use the following to help you track them down: cd /aips++/daily/code; find . -name module.help -print)

The .help files are used for two purpose, one generate standard LaTeX for a "printed" reference manual (Refman) and the other to generate glish help atoms for use by the help function in glish.

To generate the LaTeX document, there is a special helpsys target in the code/doc/user makefile. It searches the active code tree, (trial, aips, synthesis, and nrao) for all files ending in a .help, .ps, and .eps extension. Once the documents are collected, help2tex is run on the package helpfiles and .htex files are produced. These .htex files are compared with the existing ones in docs/user/helpfiles and if different updated. The .ps and .eps files are also moved to this directory if necessary. Help atoms file for glish are generated if necessary at this time by help2tex. The standard .latex rules take over after all the copying is done.

We encourage your to check out your help file by doing the following,

```
gmake myfile.dvi
```

The gmake runs help2tex on the file myfile.help and then runs latex on the resulting ".htex" file. It's important to make sure your .help file runs through the process clean. If it fails any documentation that follows won't be included in the Refman. If have relative-outside links in your .help file or links to other parts of the Refman, they will be hi-lighted but the hyper-links will fail when built in the "programmer" tree. This happens because of three things:

1. The docs tree has a different number of directories compared to the programmers code tree,
2. The external documents won't be in your tree, and
3. You are only building a small fraction of the reference manual and it's entirely out of context.

Currently checking links to external documents in the aips++ docs tree, requires specifying a DOCSROOT and building the Refman and the external document you need to check against (gmake docsys DOCSROOT=/mydocs). Note for gmake docsys to work, you need to ai and au your help file, cd code/doc/user and then run the gmake.

7 Creating Distributed Objects

Although substantial applications can be written entirely in Glish, in many cases one has to provide functionality via C++ code. The binding of C++ to Glish is done using *distributed objects.* This section takes you through a trivial example of a distributed object.

First we have to understand the AIPS++ "tasking" model. The basic model is as follows:

1. Computation occurs in C++ objects defined by the application programmer.
   - The system takes care of creating and checking the parameters the application programmer needs. For instance, if an application needs an image, the system will make sure the image exists and opens it for the programmer, rather than, e.g., just handing the programmer a String (a file name) and requiring him to do the error checking.
   - The system provides some standard services to the application programmer.
2. A process (running executable) can contain many objects from one or more classes. The system takes care of creating the objects and invoking their functions when the user requests it.
3. For each C++ class, a glish "proxy" that manipulates it is created by the application programmer. The system takes care of the link between this proxy and the actual C++ object.

The overhead for the application programmer is approximately 10 lines of C++ and 10 lines of glish per method (more if there are many arguments). It might plausibly however require less total lines of code than previously since, *e.g.,* the programmer has less error checking and parameter conversion to do, does not have to write an event loop, and so on. Perhaps more importantly, because these things are done by the system, the user will see a more uniform interface, and improvements to that interface can occur in a centralized fashion.

The execution overhead is such that you shouldn't expect more than about 150 DO no-op method invocations per second on a Sparc-20 sized machine (less if the methods are transferring a lot of data or for methods which have parameter logging turned on). For weighty or infrequently called computations this should be sufficiently fast, otherwise you may have to batch or cache to improve the performance.

For our example, suppose we want to provide a "squarer" class that merely squares an integer. Obviouly you would never create a distributed object to do this, but it makes a small example that can be entirely contained in this paper. It is also checked into the system as `trial/Tasking/test/dsquarer.cc` and `trial/Tasking/test/dsquarer.g`.

7.1 Implement your computation

Once you have decided what your interface is to be, implement the computational portions of it as you would any other class. If the class is merely relaying functionality that already exists in the library (*e.g.*, FFT's) the class should be checked into the applications own directory, otherwise it should be checked into a general library directory so other C++ users can access it directly. All interesting functionality programmed into AIPS++ should be available in the libraries, it must not be "locked up" entirely in an application.

Unlike the rest of the AIPS++ library, DO class names will be entirely lowercase. Because of this, if you check the class into the general system, do so in the "distributed" directory to avoid having different case conventions in general library modules.

In our case, the class has no intersting functionality, and we would just check it into the application directory that contains the server that we will use. If this was a real example, we would probably use the "numerics" server.

Here is the "computational" class before becoming a distributed object (DO):

```
#include <aips/aips.h>

class squarer
{
public:
    squarer() {}
    squarer(const squarer &other) {}
    squarer &operator=(const squarer &other) {return *this;}
    ~squarer() {}

    Int square(Int  x ) { return  x * x  };
};
```

Some comments on the above:

- Unlike our usual practice, the class is all lowercase to reflect the fact that it will be in lower case in Glish (it would be far too confusing to have different cases for the same class in Glish and C++).
- The system will never make use of the copy constructor or assignment operator, however you should probably still provide them for direct C++ users of your class. If you do not provide them, declare them in the private part of your class `.h` file.
- As described later, it is easier for you if the only constructor[2] you have is the default constructor. If, however your class does not have a sensible "default" object you should not provide a default constructor. Objects should always be valid.

You should test and debug your class at this point using test programs *etc.*, until you are convinced that the computational part of your class is correct. If the class is to be checked into the general library the test programs should also be checked in with the class.

[2]Not counting the copy constructor.

7.2 Create an ApplicationObject

All that is needed to turn your computational class into a distributable one is that you define what parameters your methods need, and you tell the system what method to actually run for a given method name (i.e., a `String`). The is done by publicly *deriving* your class from the base class `ApplicationObject` and filling out three required methods.

Here is the class as a DO:

```
#include <aips/aips.h>
#include <trial/Tasking.h>                                          // 1

class squarer : public ApplicationObject                            // 2
{
public:
    squarer();
    squarer(const squarer &other);
    squarer &operator=(const squarer &other);
    ~squarer();

    Int square(Int  x );

    virtual String className() const;                               // 3
    virtual Vector<String> methods() const;                         // 4
    virtual MethodResult runMethod(uInt which,                      // 5
                                   ParameterSet &parameters,
                                   Bool runMethod);
};
```

The changes from before are as follows:

1. This file defines the class `ApplicationObject` and other things that will be needed latter.
2. All DO's must publicly inherit from `ApplicationObject`.
3. It is required that this method be provided. It returns the name of the class, `squarer` here.
4. This method must also be provided. It returns a Vector with the name of all the methods that you want to be attached to the DO system. That is, you do not need to list "helper" methods you implement for your own use, or system methods like `methods` itself. Here you would only return `square`.
5. This is the method that the system will call, and from which you will in turn call the "real" routine. The parameters have the following meanings:

   which Which parameter number to run. This is the (0-relative) index of the function name returned by `methods()`.[3]

[3] You might wonder why `which` is an index rather than a `String`, which would be somewhat safer. The reason is efficiency — the system can turn a method name into an integer fairly efficiently, and a case on an integer is more efficient than a long set of `if (string1 == string2)` statements.

parameters This is the object into which you will get the argument for `square(Int x)` and set the return value.

runMethod If `False`, define the parameters, otherwise get the parameters, run the method, and return the result.

It would probably be useful to see the actual implementation for `runMethod()`:

```
MethodResult squarer::runMethod(uInt which,
                                ParameterSet &parameters,
                                Bool runMethod)
{
    static String xName = "x";                                  //  1
    static String returnvalName = "returnval";                  //  2
                                                                //  3
    switch (which) {                                            //  4
    case 0:                                                     //  5
    {                                                           //  6
        Parameter<Int> x(parameters,                            //  7
                            xName, ParameterSet::In);           //  8
        Parameter<Int> returnval(parameters, returnvalName,     //  9
                                 ParameterSet::Out);            // 10
        if (runMethod) {                                        // 11
            returnval() = square(x());                          // 12
        }                                                       // 13
        break;                                                  // 14
    default:                                                    // 15
        return error("Unknown method");                         // 16
    }                                                           // 17
    return ok();                                                // 18
}                                                               // 19
```

1. A small point, but it will make things slightly faster if strings which have the same values upon each invocation are created `static` — this will prevent the same values from being created over and over again.

2.

3.

4. Even though this class only has one method, I would still set up a switch so that it will be easier to insert more methods later if we need to.

5. Zero-relative method number, i.e. you would use this to index into the `methods()` vector.

6.

7. We have a single integer parameter named `x`. It is an input only value, i.e. it does not need to be copied back. `InOut` is another alternative for "reference" parameters. Parameter names may not begin with an underscore.

8.

9. This is the returned value. `returnval` is a special parameter name, and you may not use it for any other argument. Void functions merely omit having a parameter named `returnval`. Note that pure output parameters should be set to `ParameterSet::Out`, whereas any parameters which are both input and output (used and set) should be marked `ParameterSet::InOut`.

10.

11. Only run the method if we're told to (otherwise we're just *defining* the parameters we need).

12. Run the function. The Parameter function operator (`operator()`) returns a reference to a value of the template type, `<Int>` here.

13.

14. Don't forget the break or you'll end with an error even though all is well with your method.

15. While the system should never call this function with an invalid `which`, defensive programming is always a good idea.

16. `error()` is a predefined function that takes a string and returns an error to the system. Use it whenever you can detect an error before running the function (which probably won't be very often). Do not bother catching unexpected exceptions and then returning `error()` — the system will do this for you.

17.

18. `ok()` should be returned whenever `runMethod` ends normally.

7.3 Other ApplicationObject methods

Other methods inherited from `ApplicationObject` which it might be useful for you to be aware of are shown next:

```
class ApplicationObject
{
    ...
    virtual Vector<String> noTraceMethods() const;
    const ObjectID &id() const;
    static MethodResult ok();
    static MethodResult error(const String &message);
    ...
};
```

Some comments:

noTraceMethods() Normally, methods in a DO have some automatic logging applied when executed (input and output parameter values, execution times). This is the right thing to do for "weighty" computations (*e.g.*, a deconvolution), but is inappropriate for small computations that might be called many times, or for functions whose return value says everything there is to be known about the function (*e.g.*, `image.shape()`. Return the names of functions which you don't want logged. This is the only function in this section which may be over-ridden — the default is to return no function names, *i.e.*, log all functions.

id() Return our `ObjectID`. This function is useful in setting up the `LogOrigin` for logging, and possibly for retrieving objects from the `ObjectController` as described in Section 7.6.

ok() A convenient way to produce a "normal" error return: `return ok();`

error() A convenient way to indicate a problem occurred in this function: `return error("message");`

7.4 Parameters and Constraints

The goal of the `Parameter<T>` class is to have the system provide objects of the class the programmer actually wants, and error checking them for the user. You should tell us if there are unsupported types that would make your life easier.

Presently, the supported `<T>`'s are:

Scalars Bool, Int, Float, Double, Complex, DComplex, String.

Arrays of the scalar types.

Vectors of the scalar types. Vectors are provided explicitly so you don't have to check that an `Array` is of the correct dimensionality.

Index `Index` and `Vector<Index>` This types is used for values which are zero-relative inside C++, but one-relative to the user. So, you would use a `Vector<Index>` for a pixel in an image, but a `Vector<Int>` for its shape. You would use an `Index` for the row number of a `Table`, and an `Int` for the number of rows it contains. Correct use of this class should greatly reduce the number of "off-by-one" errors in the system.

Glish values `GlishArray` and `GlishRecord` and `GlishValue` are available as parameter types. You would use the former for methods that, e.g., take the FFT for a wide variety of pixel types, and you would use the latter where you want an inhomogeneous container ("header"). For example, the signature of a function that computes statistics on an array of any type and returns those statistics in a record might be:

```
        // return record like [mean=0, variance=1.0] for any type
GlishRecord class::statistics(const GlishArray &a) const;
```

Data classes `PagedImage<Float>` and `Table`.

Quantum If you need a quantity with a unit, you should use this type rather than just a double and assuming the units. Only `Quantum<Double>` is available so far. For example, use this if you need a duration, or a shift of an image.

ObjectID Unique object identifiers, as returned by the `id()` member function.

Note that the normal Glish conversions will happen automatically for the scalar and array types,. In particular, a numeric type may be retrieved as any other numeric type.

At present we envisage that ultimately we will provide in addition to the above:

MeasurementSet, The measure types (MPosition et al.), some Functionals (Gaussian and Polynomials), Matrix, Cube(?), Record.[4].

Let us know when you need parameters of the above, or other, types.

As described briefly in the previous section, Parameters are defined with the following constructor:

```
template<class T> class Parameter
{
    ...
    Parameter(ParameterSet &parameters, const String &name,
              ParameterSet::Direction direction);
};
```

The first time this constructor *defines* is called a parameter with the given name and direction is defined in the given parameter set. The parameter value may not be used, since the parameter has just been defined — it cannot have been filled in yet! The second time time it is called the parameter to the value in the supplied parameter has been set, and hence you may use it. Note that it is a mistake to define more than one parameter with the same name (this mistake will be caught by the `ParameterSet`.

The name may be any string except one beginning with an underscore, which are reserved for system use. The name `returnval` is used for function return values — do not use it for any other purpose. The direction must be oe of `ParameterSet::In`, `ParameterSet::Out`, or `ParameterSet::InOut`.

7.4.1 Constraints

While *defining* a `Parameter<T>`, a `Constraint<T>` may be attached. This is done so that the system can perform extra error checking on your behalf.

The following constraints are available:

ParameterRnge for scalar values, *i.e.*, $min \leq param \leq max$. For example, if you wanted to restrict an angle to the range $0 \leq \theta \leq \pi/2$ you could do so as follows:

```
Parameter<Double> theta(params, "theta", ParameterSet::In);
theta.setConstraint(ParameterRange<Double>(0.0, C::pi/2.0);
```

NewFile for strings which are to be used for output files. If the file already exists, the use has an opportunity to delete it. The default is to not overwrite the file.

```
Parameter<String> outfile(params, "outfile", ParameterSet::In);
outfile.setConstraint(NewFile());
```

If you find yourself doing error-checking on your parameters that you think would be usefully embedded in a constraint, please let us know.

[4]However, it will be more efficient to transport `GlishRecord` because a conversion will be avoided.

7.5 Embed your class in a server

Once you have created your DO class, it is remarkably easy to create a server executable to embed it in.

Here is the main program for a DO server executable:

```
#include <aips/Tasking.h>
#include <your includes go here>

int main(int argc, char **argv)
{
    ObjectController controller(argc, argv);
    controller.addMaker("squarer", new StandardObjectFactory<squarer>);
    controller.loop();
    return 0;
}
```

You can call `addMaker()` for as many different classes as you want to embed in the current server. Generally you will want to group multiple classes of similar purpose (*e.g*, synthesis processing) into one server executable to amortize the amount of disk and memory use used by the greedy C++ compilers. So, for example, the `numerics` server is used for FFT's, fitting and the like, and the `image` server is used to serve DO's for all image-plane only functionality. Note that the `ObjectController` will delete the factory when it is done with it — you must not delete the pointer yourself.

A *Factory* is a class that knows how to create another class. In particular, `StandardObjectFactory<type>` is a class that know how to create objects of any `type` that has a default constructor. Currently with the GNU compiler you will need to create an extra line in the `templates` for each new use of `StandardObjectFactory<T>`.

7.6 Application services

An application services is some utility class or function that application programmers can call to interact with their users or the system. The presently implemented or envisaged services are:

Logging Messages posted to the global sink will be sent to Glish and displayed to the user in some fashion he specifies, and eventually saved to a log table. As described above, parameter values and time information will be logged automatically by the system, so you do not need to log that. Otherwise, you should err on the side of logging too much than too little — you can always change the filter to `DEBUGGING` level if the user is seeing too much information. Logging is described in `Logging.h`.

Hints The following hints are available as static functions in class `ApplicationEnvironment`. The hints are not guaranteed to be correct — they (will) rely on values set at installation time — however the default values are lowest-common-denominator values. [We need to figure out where to document these sorts of installation values — aipsrc in this case].

memoryInMB() Physical memory of the host system.

nProcessors() Number of processors.

isInteractive() Are we being run interactively — if not you might, e.g., change your data display strategy.

choice() Present some descriptive text and set of (string) possible answers to the user (the choices will appear in buttons). For example, "File exists, over-write? no/yes." For non-interactive use the first (i.e. default) choice will be returned.

Object access It might be useful to obtain access to another DO that is running in the same server. You can do this as follows:

```
void myclass::method(const ObjectID &id)
{
    ObjectController *controller =
                         ApplicationEnvironment::objectController();
    if (controller == 0) { ... no controller is running - error ...}
    ApplicationObject *obj = controller->getObject(id);
    if (obj == 0) { ... no object 'id' in the controller - error ...}
    // Presumably you'd call obj->runMethod here
}
```

Do not delete either of the pointers! Similarly, your class can make an object and put it into the `ObjectController` using a similar process.

Aipsrc This is a method to get resources out of the `.aipsrc` files. [reference?] These will often be used to, e.g., over-ride the location of standard files, e.g. IERS data. *not yet implemented (but soon)*

Progress Display a "sliding bar" visual indication of how far a (typically) long-running process has progressed. A no-op for non-interactive sessions. *not yet implemented*

PGPlotter Plotting (both line and graphics) is available through the PGPlotter class. The preferred way for an application to get its PGPlotter is via `ApplicationEnvironment::getPlotter`.

7.7 Exception strategy

If you can meaningfully handle an exception from lower down in the library you should of course handle it and proceed with execution. If you cannot handle an exception, there is no point in catching it. One exception might be to rethrow an exception with a more comprehensible error message[5] — often you, the "high-level" programmer will know what the likely user-level error is apt to be, whereas the "low-level" library programmer may not be able to provide a meaningful error message.

Similarly, if you detect some error condition you cannot handle, you should throw an exception with an informative error message — ideally one that states what the likely problem and cure is.

Since we don't want to discourage defensive programming, assertions testing for "cannot happen" errors need have no descriptive text, *e.g.*:

[5]The message in an uncaught exception will be presented to the user, along with the name of the class and function he invoked that ultimately resulted in the exception.

```
    Type *ptr = new ...;
    AlwaysAssert(ptr != 0, AipsError);
```

7.8 Non-standard constructors

You can ignore this section if your class only has a default constructor and (possibly) a copy constructor. In this case `StandardObjectFactory<type>` suffices.

If, however, your DO class does not have a default constructor, or if it has multiple constructors which you want to give users access to, you must create your own factory class. To do this entails two steps:

1. Derive a new class from the abstract base class `ApplicationObjectFactory`.
2. Override its `make()` method using a technique essentially identical to the `runMethod()` technique we saw earlier.

Suppose we are creating an `image` DO that lets the user directly manipulate an AIPS++ `PagedImage` object. There is no sensible "null" object for such a class, and in fact we might wish to have multiple constructors:

```
class image : public ApplicationObject
{
public:
    // Attach to an existing image
    image(PagedImage<Float> &theimage);
    image(const String &imagefile, const String &fitsfile, Index whichhdu);
    ...
};
```

To create objects of this class, we need to create a special purpose `ApplicationObjectFactory` and override its `make()` method. This would probably be the only member function in the class.

```
class imageFactory : public ApplicationObjectFactory
{
    virtual MethodResult make(ApplicationObject *&newObject,
                              const String &whichConstructor,
                              ParameterSet &inputRecord,
                              Bool runConstructor);
};
```

This would be implemented with a technique essentially the same as we saw earlier with `runMethod()`, however since we expect the object creation rate to be low compared to the member function creation rate, we `if` on the constructor name directly. The constructor name is assigned by us, and may be anything so long as each constructor has a unique name.

Here is a sketch of an implementation for an Object factory with two constructors.

```
MethodResult imageFactory::make(ApplicationObject *&newObject,
                              const String &whichConstructor,
                              ParameterSet &parameters,
                              Bool runConstructor)
{
    MethodResult retval;                                          // 1
    newObject = 0;                                                // 2

    if (whichConstructor == "image") {                            // 3
            Parameter< PagedImage<Float> > theimage(parameters,   // 4
                                            "theimage",
                                             ParameterSet::In);
        if (runConstructor) {                                     // 5
            newObject = new image(theimage());                    // 6
        }
    } else if (whichConstructor == "fits2image") {                // 7
        ...
    } else {                                                      // 8
        retval = String("Unknown constructor ") + whichConstructor;
    }

    if (retval.ok() && runConstructor && !newObject) {            // 9
        retval = "Memory allocation error";
    }
    return retval;
}
```

Some comments:

1. Assume this routine works until we discover otherwise.
2. This point at an object of the created type, allocated with new. Initialize with zero.
3. Write an "if" for each possible constructor. You can use arbitrary names, however I suggest using the names that are the same as the name you will give the corresponding function in Glish.
4. Just like in `runMethod` first we define the parameters. Here we want an image.
5. If `runConstructor` is false, we are only defining parameters. If true, we actually want to create an object.
6. Create the object. We will check that new succeeded later. The image parameter has already been instantiated, so you don't need to check that it exists, has the right pixel type, and so on.
7. Another constructor.
8. Defensive programming — make sure we catch unknown constructors. Since `newObject` was initialized with zero, the system would have caught the error even without this line, but the error message would be less descriptive.

9. Here we check once for all constructors that the new succeeded. We could also have done this in each “if” branch.

The other place the names of the constructors will be used is in the Glish construction functions, see section 8.1.

8 Binding Distributed Objects to Glish

Next we show the Glish code necessary to bind this class so that the user can manipulate it directly.[6]

```
if (! is_defined('squarer_g_included')) {                         #  1
    squarer_g_included := 'yes';

include "servers.g"                                               #  2

const squarer := function(host='', forcenewserver = F) {          #  3
    self := [=]                                                   #  4
    public := [=]                                                 #  5

    self.agent := defaultservers.activate("dsquarer", host,       #  6
                                    forcenewserver)

    self.id := defaultservers.create(self.agent, "squarer")       #  7

    self.squareRec := [_method="square",                          #  8
                       _sequence=self.id._sequence]
    public.square := function(x) {                                #  9
        wider self                                                # 10
        self.squareRec["x"] := x                                  # 11
        return defaultservers.run(self.agent, self.squareRec)     # 12
    }

    return public

}  # constructor
}  # include guard
```

Some comments on individual lines:

1. This is how you implement an include guard in Glish, to prevent multiple-inclusion of the file.
2. This file must be included — it contains the code that knows how to communicate with the server executables and DO’s.

[6] It is also technically feasible to allow the user to invoke this functionality from the Unix command line, however this is presently not a high priority for us.

3. This global function is the glish equivalent of our default constructor — and it will end up calling the default constructor. Normally the system will keep all the objects in the same server process, however you can force new server processes (possibly on different hosts on the network) if the user wants to to use coarse-grained parallelism. Constructor functions, like most global functions and objects, should be const to prevent users from accidentally overwriting them. We shall see later how to bind classes with non-default constructors.

4. This record will hold our private data.

5. This record will hold our public member functions. It is the users interface to the DO.

6. This activates a server process if necessary. `dsquarer`[7] is the name of the binary executable on disk (it must be in the path). This is the line that maps the name of the class to the name of the executable that serves it. `defaultservers` implements the communication link to the server and its DO's.

7. This line creates the DO in the server of the specified type. In the event of an error, a Glish `fail` will be returned.

8. While you could create the record that is passed back and forth to the DO afresh each time, it is most efficient to cache it so it is created only once. You must always set the method name and sequence number. Note the leading underscores!

9. This is the `square()` member function proxy that will invoke the *real* function in the DO.

10. This is a bit of Glish magic that you need to get at your private data. If you want access to the other member functions in this function you would also need `wider public`.

11. Put the supplied parameters into the record that will be passed to the DO.

12. Invoke the actual function in the DO. Note that if you had `Out` or `InOut` parameters, the glish arguments would be of type ref, and you would have to change the arguments before returning. For example, suppose "a" was changed in place, then this function would look like:

```
public.square := function(ref x) {
    wider self
    self.squareRec["x"] := x
    returnval := defaultservers.run(self.agent, self.squareRec)
    val x := self.squareRec.x
    return returnval
}
```

8.1 Binding objects with non-standard constructors

If you are only using the default constructor, you can ignore this section.

If you have a DO class with more than one constructor, you need to have more than one global function that constructs the object. To do this, you:

[7]Typically, the server name of the binary on disk will either be the name of the most important class that it is serving, *e.g.*, `image`, or it will be a name descriptive of the types of classes that it is serving, *e.g.*, `numerics`.

1. Factor out the code that sets up the public functions into a global function unintended for general consumption; and
2. Call that function from each constructor function.

This is illustrated in the next code fragment. To hide the common creation function, we suggest that there names begin with an underscore and that they not be documented in user documentation.

```
const _define_image := function(ref agent, id) {
    self := [=]
    public := [=]

    self.agent := ref agent;
    self.id := id;

    ... Define the functions here ...
    return public
} # _define_image()

const image := function(filename, host='', forcenewserver=F) {
    agent := defaultservers.activate("image", host, forcenewserver)
    id := defaultservers.create(agent, "image", "image",
                        [theimage=filename]);

    return _define_image(agent,id);

} # image()

const fits2image := function(imagefile, fitsfile, whichhdu=1,
                             host='', forcenewserver=F) {
    ... create using the fits2image constructor ...
} # fits2image()
```

9 Testing Your Application

Provide a test global function called `yournametest()` (*e.g.*, `imagetest`) inside the `.g` file that contains your application code. Exercises all the functionality as thoroughly as possible. This should be similar to the demonstration function but much more complete. If the test runs correctly, return True, otherwise return False. Remember to test failure modes as well as things that are supposed to work!

10 Debugging Your Application

At present, the tasking system offers two things that might aid you in debugging:

defaultservers.trace(T) If you type this in Glish, the glish values that are actually transferred back and forth over the Glish bus will be traced as log messages from both the Glish and C++ side of the connection. Also, the priority for display of log messages is lowered to `DEBUGGING` level.

defaultservers.suspend(T) If you type this in Glish, every time a new server (*i.e.*, binary executable) is started up, it will print the pid and suspend the client as described in Section 10.2.1 of the Glish(2.6) manual to allow you to more readily attach a debugger to it. Note that after you attach to the binary, you need to set the "suspend" variable to "0" in the C++ executable. (With the sun native compiler when you attach you are at the right level, with g++ you need to go "up" the stack two levels first).

Of course entering `F` instead of `T` in the above will turn off that debugging option.

Let us know of any other system debugging support that might be useful to you.