New Technical Notes

Macintosh

Developer Support

Pascal to C: PROCEDURE Parameters

Platforms & Tools

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This Technical Note talks about nested procedures and `PROCEDURE` parameters in Pascal and what to do when converting them into C or C++.

Changes since February 1990: Fixed some type coercion problems.

Pascal and C offer many of the same features, but there are some differences. These differences make converting between languages or calling libraries written in one language from the other difficult sometimes. Two closely associated features of Pascal that C does not offer are nested procedures and `PROCEDURE` parameters. Since these two features are commonly used when programming with MacApp, the problem of implementing them in C++ is a common one.

How Pascal Implements Nested Procedures

Pascal lets programmers nest procedures within each other. Doing so allows one to limit the scope of local variables, as well as allow multiple procedures access to the same set of dynamically created variables.

Let's take a look at the following bit o' code:

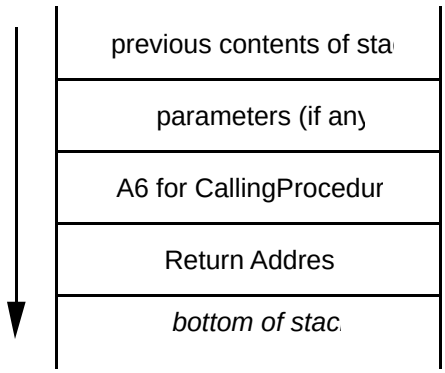
```
PROCEDURE CallBack;                { Outer level procedure }

  BEGIN
  END;

PROCEDURE CallingProcedure;        { Outer level procedure }

  VAR
    aVar: integer;

  PROCEDURE NestedCallBack;        { Nested procedure - can access "aVar" }

    VAR
      anotherVar: integer;

    BEGIN {NestedCallBack }
      aVar := 1;
      anotherVar := 2;
    END; {NestedCallBack }
```

```
BEGIN {CallingProcedure }
  CallBack;
  NestedCallBack;
END; {CallingProcedure }
```

This code shows three Pascal procedures: `CallingProcedure`, `CallBack`, and `NestedCallBack`. `NestedCallBack` is the nested procedure, which means that it can access the local variables of the procedure it is nested within, namely, `CallingProcedure`.

The method used to allow `NestedCallBack` to access its host procedure's local variables is not so obvious and involves a little hack. As you may know, local variables are created on the stack when a procedure is entered, and the 680x0 register `A6` is initialized to point to them. Fine, but this leads to a little conflict within `NestedCallBack`. It needs to use `A6` to point to its own local variables (e.g., `anotherVar`), so how does it access its host procedure's local variables?

The answer, logically enough, is that it uses another register for this purpose. When `NestedCallBack` is called from its host procedure, the host's `A6` is pushed onto the stack after any and all formal parameters have been pushed on, but before the `JSR` is performed (this extra parameter is often referred to as the "static link"). As `NestedCallBack` is being entered, you have a stack similar to that in Figure 1. By comparison, Figure 2 shows what the stack would look like if you made a normal call to a procedure on the outer level, such as the procedure shown above named `CallBack`.



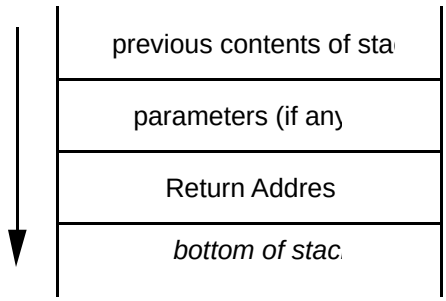


Figure 1–Call to NestedCallBack & Figure 2–Call to CallBack

Each procedure knows at compile time whether it is nested or not and adjusts itself accordingly. If it turns out that a procedure is nested, then it is compiled as if you had declared an extra parameter at the end of the formal parameter list, one that held the value of the host's `A6`. Pascal then uses this parameter for fetching the local variables of the nested procedure's host. It pulls this parameter off of the stack just like any other parameter, sticks it into a handy register, and uses it as a base address to the host's local variables, just as it uses `A6` as the base address to its own locals.

How Pascal Implements PROCEDURE Parameters

As seen in the previous section, nested procedures require a little help to get themselves up and running. Specifically, they need an extra parameter called a static link. You've seen one way in which Pascal provides support for this parameter. In this section, you see another important case.

There are many Toolbox routines that require a pointer to a procedure being passed to them as a parameter. These procedures are called "callback" procedures, because the Toolbox makes a call back to those procedures to perform some application-specific function. An example of this type of routine would be the Control Manager routine `_TrackControl`, which requires a callback procedure called `actionProc`.

By now, you should see why you cannot pass the address of a nested procedure to such a Toolbox routine. Nested procedures require that they be passed the static link parameter so that they can access their host variables. The Toolbox doesn't support this convention, so it cannot pass the required static link to the nested routine.

While the Toolbox doesn't support the nested procedure convention, Pascal itself does support a method whereby you can pass around all the information necessary to implement a callback procedure as a nested procedure. Syntactically, this is done by including a full procedure heading in the list of formal parameters a procedure takes. An example of such could look like the following:

```
PROCEDURE SomeProcedure(PROCEDURE CallBackProc(i:integer); iterForward: BOOLEAN);
  BEGIN
    ...
    CallBackProc(5);
    ...
  END;
```

`SomeProcedure` takes two parameters. The first is a `PROCEDURE` parameter that refers to a routine that takes a parameter itself, namely, a single integer. In addition, `SomeProcedure` takes a `BOOLEAN` called `iterForward` as a second parameter. You would call `SomeProcedure` with something like the following:

```
PROCEDURE MyCallingProcedure;

  PROCEDURE MyCallBackProcedure(i: integer);

    BEGIN { of MyCallBackProcedure }
      < mumble >;
    END;

  BEGIN { of MyCallingProcedure }
    SomeProcedure(MyCallBackProcedure, TRUE);
  END;
```

Through the use of the `PROCEDURE` parameter, you can invoke the callback procedure using a natural Pascal syntax. In the `SomeProcedure` example, the statement `CallBackProc(5)` causes `MyCallBackProcedure` to be called with a value of five. Not only can you just invoke the procedure by entering the name of the `PROCEDURE` variable, but you can pass parameters to it with full Pascal typechecking invoked. In this case, Pascal ensures that when you call `CallBackProc`, you also pass a single integer to it.

PROCEDURE parameters also give the support for nested procedures for which you are looking. When a PROCEDURE parameter is passed on the stack, two components are used to represent it. The first is a pointer to the actual procedure. The second is the static link. Therefore, you can think of a PROCEDURE parameter as being represented by the following record:

```
TYPE
  ProcedureParameter = RECORD
    procPtr: Ptr;
    staticLink: Ptr;
  END;
```

When you pass a PROCEDURE parameter to a destination procedure, both of these components are pushed onto the stack as LONG values (four bytes each). When it comes time for the destination procedure to invoke the callback, any necessary parameters for the callback are placed onto the stack, followed by the staticLink value. Then the routine specified by procPtr is called.

The step where the destination procedure pushes the static link onto the stack is important and should be examined more closely. Specifically, how do you know that a static link parameter is necessary at this point? After all, SomeProcedure simply declares that it takes a PROCEDURE as a parameter; it doesn't differentiate between nested and non-nested procedures. But, as you saw in the first section, these two kinds of procedures are called differently. How do you know if the the static link passed to you needs to be pushed onto the stack for the callback procedure?

The answer is that SomeProcedure receives a special value for the static link parameter for non-nested procedures. If the callback procedure is at the outer level, SomeProcedure receives NIL for the value of the static link. When Pascal compiles the commands that invoke PROCEDURE parameters, it generates code that checks the static link. If it is NIL, it doesn't push it onto the stack. If it is not NIL, then you are calling a nested procedure, and must push the static link onto the stack.

So, how do you utilize nested procedures and PROCEDURE parameters in C or C++? Obviously, you cannot—at least not directly. C and C++ don't support them. At this point, you might as well just give up and use Pascal; you always said C++ was highly overrated anyway.

There are two scenarios to examine:

- A Pascal routine calls your C++ routine, passing a PROCEDURE parameter to another Pascal routine you have to call.
- Your C++ routine calls a Pascal routine expecting a PROCEDURE parameter, which you have implemented in C++.

The rest of the Note looks at both of these cases.

Pascal to C++ to Pascal

MacApp supports an object inspector, which it implements by calling a `Fields` method common to all descendants of `TObject`. Each class you define should override this method so that MacApp can find out about your class's fields. Such a method definition would look like the following:

```
PROCEDURE TJustCommand.Fields(PROCEDURE DoToField(fieldName: Str255; fieldAddr:
Ptr;
                                                  fieldType: INTEGER)); OVERRIDE;

BEGIN
  DoToField('TJustCommand', NIL, bClass);
  DoToField('fTEView', @fTEView, bObject);
  DoToField('fOldJust', @fOldJust, bInteger);
  DoToField('fNewJust', @fNewJust, bInteger);
  INHERITED Fields(DoToField);
END;
```

You tell it the name of your class so that whatever routine is calling you (usually MacApp's inspector or debugger) can identify the class it is inspecting. Then, for each field in your class, you call the procedure passed to you, giving it the three parameters it needs. Finally, you call your superclass' `Fields` method so that it can identify its name and fields.

When your `Fields` method is called, the `DoToField` parameter appears on the stack as a pointer to the procedure you are supposed to call, as well as the static link value it needs. When you actually call `DoToField`, the necessary parameters are first pushed onto the stack (i.e., `fieldName`, `fieldAddr`, and `fieldType`). Pascal then adds some code that makes a determination based on the value of the static link parameter. If it is non-zero, then you are calling a nested procedure and need to pass back the static link back on the stack. If static link is zero, then you are not calling a nested procedure and don't need to pass that static link back.

Pascal handles all of this for you transparently. This ease in Pascal makes the process of writing a similar routine in C or C++ that much more difficult, as that process has been hidden from us.

There is no way in C or C++ to pass a variable number of parameters in one statement. In other words, you **cannot** do something like the following:

```
DoToField("\pTJustCommand", nil, bClass, StaticLink ? StaticLink : void); /* No Workie */
```

That would be too easy. Instead, you must use some inline glue that prepares the stack for you. This inline procedure accepts the three parameters you see in the Pascal version, as well as both components of the `PROCEDURE` parameter (i.e., the procedure pointer and static link). The glue looks at the static link value and removes it from the stack if it is zero and, thus, not needed.

One solution is as follows:

```
typedef pascal void (*FieldProcPtr) (StringPtr fieldName, Ptr fieldAddr,
                                     short fieldType, void *DoToField_StaticLink);
```

```
pascal void CallDoToField(StringPtr, Ptr, short, void *, FieldProcPtr)
 = {
   0x205F,    // MOVEA.L    (A7)+,A0    ; get the DoToField pointer
   0x4A97,    // TST.L      (A7)        ; check the StaticLink
   0x6602,    // BNE.S      *+$0004     ; if non-zero, keep it in
   0x588F,    // ADDQ.L     #$4,A7      ; if zero, pull it off
   0x4E90     // JSR        (A0)        ; Call DoToField
   };

pascal void TJustCommand::Fields(FieldProcPtr DoToField, void *DoToField_StaticLink)
{
 CallDoToField("\pTJustCommand", NULL, bClass, DoToField_StaticLink, DoToField);
 CallDoToField("\pfTEView", (Ptr) &fTEView, bObject, DoToField_StaticLink,
               DoToField);
 CallDoToField("\pfOldJust", (Ptr) &fOldJust, bInteger, DoToField_StaticLink,
               DoToField);
 CallDoToField("\pfNewJust", (Ptr) &fNewJust, bInteger, DoToField_StaticLink,
               DoToField);
 inherited::Fields(DoToField, DoToField_StaticLink);
```

C++ to Pascal to C++

Now look at another case that occurs often in MacApp. This is where your C++ routine calls a MacApp procedure that needs a `PROCEDURE` reference back to one of your own routines. For instance, MacApp has a class called `TList` that allows you to maintain a list of objects. This class has a method called `Each` that allows you to perform some operation on each object in the list. MacApp takes care of iterating over all of the objects and calls a routine you pass to it for each one.

For this example, you have a list of objects stored in a `TList` and you want to pass the `Graze` message to all of them. At the same time, you want to keep track of how many grazed so much that they fell off a cliff during the process. If the number of objects grazing off a cliff is greater than some threshold, then you call `_SysBeep`. You could use the following procedures to accomplish this in Object Pascal:

```
VAR
  myList: TList;

PROCEDURE TMyApplication.GrazeAll;

  VAR
    offTheCliff: integer;

  PROCEDURE DoGraze(theObject: TObject);

    BEGIN
      TGrazer(theObject).Graze;
      IF TGrazer(theObject).GrazedOffTheCliff THEN
        offTheCliff := offThecliff + 1;
      IF offTheCliff > SELF.fCliffThreshhold THEN
        ApplicationBeep;
    END;

  BEGIN
    offTheCliff := 0;
    myGrazerList.Each(DoGraze);
  END;
```

You use a nested procedure so that DoGraze can access the local variable offTheCliff. This allows you to use a variable that has limited scope and that is created dynamically so that you don't have to allocate a global variable. Also, since DoGraze is embedded within a TMyApplication method, you have access to the this symbol (this is the equivalent to SELF in Object Pascal).

Therefore, the problem for C++ programmers here is that there is no implicit support for getting access to local variables, such as offTheCliff, as well as the reference to the correct object through this. So what's the alternative for C++ programmers in a case like this?

First, let's take a quick look at how the Each method is declared:

Object Pascal

```
TList = OBJECT (TDynamicArray)
 ...
 PROCEDURE TList.Each(PROCEDURE DoToItem(item: TObject));
 ...
 END;
```

C++

```
class TList : public TDynamicArray {
 public:
 ...
 virtual pascal void Each(pascal void (*DoToItem)(TObject *item, void
                          *DoToItem_StaticLink), void *DoToItem_StaticLink);
 ...
}
```

As you can see, the two components of the PROCEDURE parameter have to be declared explicitly in C++. Because of this, you can come up with four different solutions to the problem, and all of them hinge on being creative with what you pass for the static link parameter.

1. Case: You need access to this, but don't need to access any local variables. Pass this in DoToItem_StaticLink directly.

2. Case: You need access to a single local variable, but not SELF. Pass the reference to that local variable in DoToItem_StaticLink.

3. Case: You need access to multiple amounts of information, including more than one local variable and this. Pass a pointer to a struct that contains this information.

4. Case: You don't need access to anything from the host procedure (including local variables and this). Pass a NIL for the static link.

Now to look at each of these in more depth.

Pass this in DoToItem_StaticLink Directly

This is the approach where you would pass this as the DoToItem_StaticLink value. You would want to do this if you needed to access your object, but didn't need to access any

local variables. Here's what some C++ code would look like using this method. You pass `this` as the static link parameter and convert it back into an object reference in your callback procedure.

```
pascal void DoGraze(TObject* item, void* staticLink) {
   TMyApplication *self;

   self = (TMyApplication *) staticLink;
   self->DoSomethingElse();
   ((TGrazer *)item)->Graze();
}

pascal void TMyApplication::GrazeAll() {

   myGrazerList->Each(DoGraze, this);
}
```

Pass the Reference to a Single Local Variable in DoToItem_StaticLink

You would use this method if all you had to do was access a local variable of your host procedure. Getting to your local variable is now just a matter of dereferencing the `staticLink` parameter.

```
pascal void CountGrazers(TObject* item, void* staticLink) {
   int *grazerCountPtr = (int *) staticLink;

   ++(*grazerCountPtr);
}

pascal void TMyApplication::GrazeAll() {
   int grazerCount = 0;

   myGrazerList->Each(CountGrazers, &grazerCount);
}
```

Pass a Pointer to a struct in DoToItem_StaticLink

If you need to pass multiple amounts of information, such as more than one local variable, possibly including a reference to `this`, you can do so with a `struct`. This `struct` would hold all the local variables you need to pass to the callback routine. You would declare an instance of this `struct` in your local parameter list and pass a pointer to it as the static link. In your callback procedure, you would coerce the `staticLink` variable back into a `Pointer` to this `struct`, and then get all the information you need.

An example of this could look as follows:

```
typedef struct {
   int offTheCliff;
   TMyApplication *self;
} localVars;

pascal void DoGraze(TObject* item, void* staticLink) {
   localVars *hostLocals = (localVars *) staticLink;

   ((TGrazer *)item)->Graze();
   if ((TGrazer *)item->GrazedOffTheCliff()) {
       ++(hostLocals->offTheCliff);
   }
```

```
   if (hostLocals->offTheCliff > hostLocals->self->fCliffThreshhold) {
       ApplicationBeep();
   }
}

pascal void TMyApplication::GrazeAll() {
   localVars myLocals;

   myLocals.self = this;
   myLocals.offTheCliff = 0;
   myGrazerList->Each(DoGraze, &myLocals);
}
```

Pass a Zero for the Static Link

You would do this in situations where you can get by with the formal parameters that are given to you and don't need to access any of your host's local variables or the object reference. Since passing a zero means "don't push a static link onto the stack" in this convention, you have to adjust the parameter list of your callback `DoGraze` accordingly.

```
typedef pascal void (* EachProcType)(TObject *, void *);

pascal void DoGraze(TObject* item) {
   ((TGrazer *)item)->Graze();
}

pascal void TMyApplication::GrazeAll() {
   myGrazerList->Each((EachProcType)DoGraze, nil);
}
```

Which of these methods you use is up to you.

Further Reference:

- *MPW 3.0 Pascal Reference*, Chapter 8, pp. 145-147
- Your dentist, twice a year