Chapter 3

Triggers

Introduction

Triggers are table methods used to control and validate actions that affect records or the table as a whole. Triggers provide a centralized way of maintaining data and relational integrity. This chapter explains what triggers are, how they are used in 4D, and how to write them. This chapter also provides a lot of details you need to construct a reliable, high-performance system.

About Triggers

Triggers Enforce Rules

Databases have rules about how data is organized and related:

Whenever an invoice is deleted, all line items must be deleted too.

Whenever the on-hand supply of a part drops below the reorder point, a purchase order reminder must be created.

Each employee ID number must be unique.

Triggers are the code that enforce the data and relational integrity rules for your system. A trigger gives you a chance to validate an action—and stop it if necessary—before it is committed. It also gives you a chance to update related data and calculated fields whenever source data changes.

Why Triggers Are Great

Triggers are great because they run *whenever* data changes. There is no way for something to slip through the cracks. Triggers run when records are changed from any of these sources:

- A custom method
- User action in a form
- Importing records
- A Web connection
- A 4D Plug-in
- A 4D Open client

The standard rules you define for your tables are enforced no matter what. The logic resides on the server and needs to be written only once. You don't need to write different code for different types of client software, and you don't have to worry about forgetting to write the necessary code. Triggers also give you a chance to validate a table's rules before committing the record. If there is any problem, you can halt the operation.

Why Are They Called Triggers?

The term “trigger” is borrowed from the SQL world for a similar mechanism. 4D uses this term so mat SQL programmers can understand what 4D is doing. In 4D the term “trigger” refers to two related concepts:

1) Database events: Special record-related events that invoke trigger code.
2) Table methods: The code that runs in response to database events.

Database Events

You use the Table Properties dialog to selectively activate the database events that table responds to.

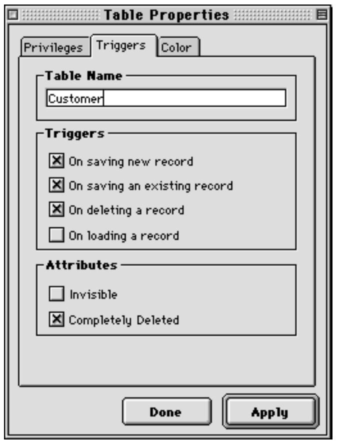


Table Properties

Privileges | Triggers | Color

Table Name: Customer

Triggers
- [x] On saving new record
- [x] On saving an existing record
- [x] On deleting a record
- [ ] On loading a record

Attributes
- [ ] Invisible
- [x] Completely Deleted

The trigger tab of the Table Properties dialog.

In this context “trigger” means the database events that cause your trigger code to run. For example:

When the customer delete record trigger runs, we need it to find and delete all related call history records.

The events listed in the triggers tab of the Table Properties dialog are called “database events” in the 4D language. You can think of them as “table events” or “record modification events”. The idea is that you have a chance to run code whenever changes to the table are committed.

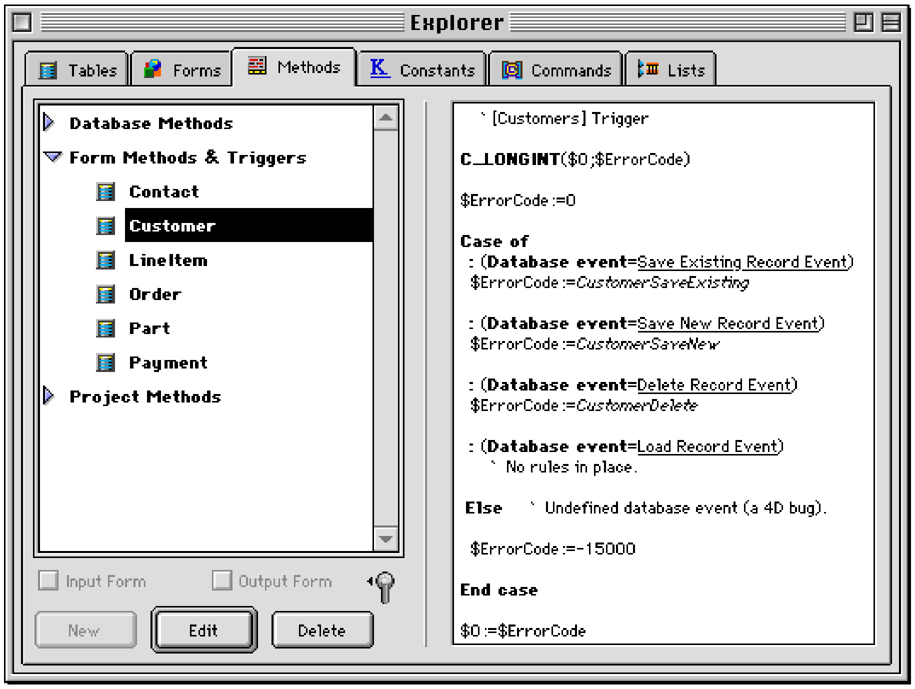
You can trap four different events:

1) A new record is being saved.
2) An existing record is being saved.
3) An existing record is being deleted.
4) An existing record is being loaded.

The loading record event is rarely useful, as discussed later on. People often ask about a “creating new record event”. This would be a useful place to put code that initializes fields and assigns sequence numbers. 4D does not include such an event because creating a record does not actually change the data. It is only when you save a new record that the data file is updated. 4D provides distinct events for saving new records and saving existing records for optimization and convenience.

Triggers are Table Methods

Triggers are another name for "table method" in 4D. You can find a table's trigger in the Explorer just where you would expect it:



```
 ` [Customers] Trigger

C_LONGINT($0;$ErrorCode)

$ErrorCode:=0

Case of
 : (Database event=Save Existing Record Event)
  $ErrorCode:=CustomerSaveExisting

 : (Database event=Save New Record Event)
  $ErrorCode:=CustomerSaveNew

 : (Database event=Delete Record Event)
  $ErrorCode:=CustomerDelete

 : (Database event=Load Record Event)
    ` No rules in place.

 Else   ` Undefined database event (a 4D bug).

  $ErrorCode:=-15000

End case

$0:=$ErrorCode
```

Triggers are table methods.

Triggers Execute On the Machine with the Database Engine

The biggest gotcha with 4D triggers is that they execute on the machine where the database engine runs. This means that under 4D they run on the current machine, and under 4D Server they run on the server machine. The effect of this is that your code can behave *very* differently under 4D Server than under 4D. Here are the key differences:

❖ If you display a window from inside of a trigger under 4D, the user sees the window. Under 4D Server it appears on the server machine!

❖ Under 4D Server the trigger has *no* access to the variables on the client machine.

❖ Under 4D Server the trigger does not have access to its own table of process variables.

Before you get too alarmed, you should know that a trigger shares several things with the client:

The current record in each table.

The current selection in each table.

The read/write state for each table.

The locked state for each record.

Process sets.

Process named selections.

Variables are the biggest area where there is a difference. Under 4D each trigger shares the process variables with the current process. Under 4D Server all triggers share a single set of process variables on the Server machine.

Triggers are Functions

Triggers are *functions* that return an error code, or 0 if there is no problem. You can return 4D errors or your own custom error codes. If you cannot perform a necessary action inside a trigger—perhaps you can't delete a related record—then returning an error code halts the operation. You can use numbers from -15,000 to -32,000 for your custom error codes. This result is returned to the client machine for handling. You will see how to handle errors shortly.

Only One Trigger Runs at a Time

Triggers run at a very low level of the database engine. Only one trigger cascade executes at a time in the entire system. (Trigger cascades are covered in detail next.) Under 4D Server only one trigger cascade runs at a time for all processes and clients. This means that in a 50 user system, when a trigger is running based on one client action no other trigger can start executing. (Imagine what happens when one of your triggers stops because of a coding error!) In real-world systems triggers perform well when used appropriately. The one-trigger-at-a-time rule does not prevent other processes from running simultaneously. Stored procedures, Web connections, and other client processes continue to execute unless they are trying to run a trigger.

The one trigger at a time rule is not documented by ACI because they may implement simultaneous triggers in the future. The defensive programming strategy is to assume that ACI will change the one trigger at a time rule in a future version. Code your system to respect today's one trigger at a time behavior, but don't rely on it. Keep your triggers small, fast, and error free. Don't program triggers that check for uniqueness assuming that no other trigger could be running simultaneously. If you need to insure that only one trigger runs at a time, use a semaphore to lock the operation.

If you are verifying uniqueness, the "unique" field attribute is the most reliable method, even today. If you use triggers to verify that a combination of fields is unique, it works today because of the one trigger at a time rule. Or does it? If your code runs inside of a transaction, it is possible for multiple processes to save the same combination of "unique" fields. The only 100% reliable way to insure uniqueness is to use a field with the unique attribute set to true.

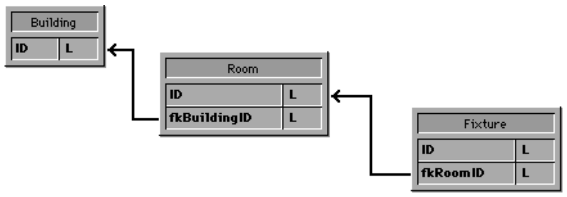
Trigger Cascades

Introduction

If a trigger changes data in another table, that table's trigger also runs, if appropriate. This is exactly how triggers should work. If a trigger could change records in other tables without invoking their triggers, you could not protect your data and relational integrity, the whole point of triggers in the first place. When a trigger performs actions that invoke another table's trigger, it is called a *trigger cascade*. Triggers may cascade to related or unrelated tables; the key is that one trigger has invoked another.

Example

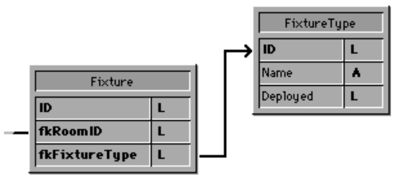
Imagine this three table relationship:



When you delete a [Building] record, its trigger deletes all related [Room] records. The [Room] trigger in turn deletes all related [Fixture] records. This cascade of triggers and deletions is exactly what you want to avoid orphaned records in your system. This is how cascading triggers are designed to work.

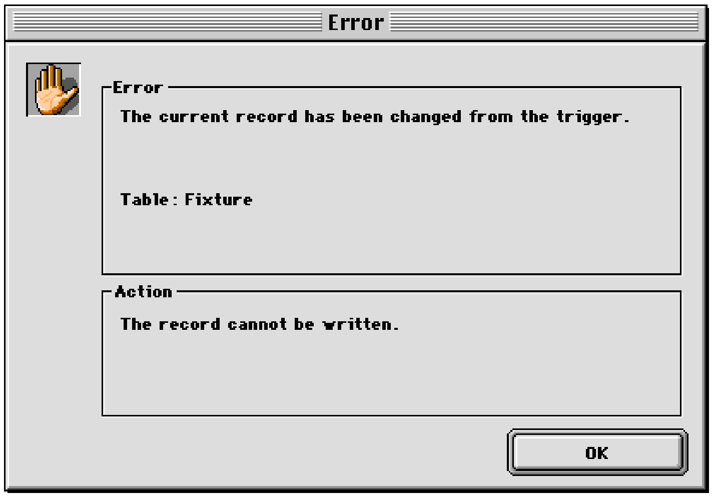
Gotcha

Consider, however, what happens when you add a fourth related table to this structure:



The FixtureType is now tracked in a new table.

The [FixtureType]Deployed field includes an up to the moment sum of how many of each fixture type are deployed in the field. This kind of summary field can deliver enormous practical benefits and is relationally defensible. But where does the field get updated? One thought would be to change the count whenever a [FixtureType] record is changed. In the example this would mean that the count would get out of date when the [Fixture] record is deleted. The [Fixture] trigger should update the value because it is the source of the change. This works perfectly. The hazard to watch out for is having the update code in two locations. If you also have the [FixtureType] trigger update the current count, what happens? When the [Fixture] changes the [FixtureType] record and saves it, the [FixtureType] trigger runs and changes the selection in the [Fixture] table. Since 4D is currently deleting a selection of [Fixture] records you have a problem. Changing the selection of a table used in an earlier trigger is like pulling the rug out from under your feet.


Error

Error
The current record has been changed from the trigger.

Table : Fixture

Action
The record cannot be written.

4D often warns you when you've changed the selection illegally.

Avoiding Trouble In Cascading Triggers

The 4D language includes commands to help you avoid trouble in cascading triggers. The **Trigger level** function tells you what level you are at. The first trigger executed is level 1, the second is level 2, and so on. The **TRIGGER PROPERTIES** lets you find out the current record, table, and database event for any current trigger level. This allows your triggers to behave differently depending on how they are invoked. If, for example, you wanted to say that [Fixture] records can only be deleted by the [Room] trigger, then the [Fixture] trigger would include code like this:

```
C_LONGINT($0;$errorCode)

Case of
  : (Database event=Delete Record Event)

    ` Deletion is allowed only from the [Room] trigger.
    ` [Fixtures] cannot be deleted directly.

  If (Trigger level<2)

    ` Level is less than 2? We don't allow direct deletion of [Fixture] records.
    ` Return an error code:

    $errorCode:=-16000

  Else

      ` Get the properties of the invoking trigger (Trigger level - 1).
    TRIGGER PROPERTIES(Trigger level-1;$invokingEvent;$invokingTableNum;$recordNum)

    ` What we want to see is that this was invoked by the [Room]
    ` delete record trigger

   $roomTableNum:=Table(->[Room])

   If ($invokingEvent  #  Delete Record Event)  |  ($roomTableNum  #  $invokingTableNum)
    ` Wrong event or table, return an error.

    $errorCode:=-16000

   Else
    ` It's OK to proceed with the deletion.
    $errorCode:=0

   End if    ` ($invokingEvent  #  Delete Record Event)  |  ($roomTableNum  #  $invokingTableNum)

  End if    ` (Trigger level<2)

End case

$0:=$errorCode
```

That looks like a lot of code just to avoid trouble! Whenever possible avoid intricate interdependencies among triggers. The simpler the design, the easier it is to implement, test, and maintain it. Now let's take a look at how to write triggers that do what you need, work reliably, and are readable.

How to Write Triggers

Cutting Edge Technique: Paper and Pen

The easiest way to write triggers is to start with a piece of paper. Write down the rules for each table in your database narratively. Before you write any code answer these questions for each table:

1) What has to happen each time a new record is saved?
2) What has to happen each time an existing record is saved?
3) What has to happen each time an existing record is deleted?
4) What has to happen each time an existing record is loaded?

If you built your database from a formal design, you already have these rules documented. If you built your database without documenting these rules, it is not too late. Putting these rules on paper costs nothing and provides these benefits:

1) It makes it simple to implement the code.
2) It makes it possible to verify that your triggers are complete.
3) It makes it possible for another programmer to work with your system.

There is a trigger development worksheet included at the end of this chapter as a reminder of the questions you need to answer before writing a trigger.

Trigger Format

This is a sample of what a trigger looks like:

```
   ` [Customers] Trigger

C_LONGINT($0;$ErrorCode)

$ErrorCode:=0

Case of
   : (Database event=Save Existing Record Event)
      $ErrorCode:=CustomerSaveExisting

   : (Database event=Save New Record Event)
      $ErrorCode:=CustomerSaveNew

   : (Database event=Delete Record Event)
      $ErrorCode:=CustomerDelete

   : (Database event=Load Record Event)
      `   No rules in place.

   Else`   Undefined database event (a 4D bug).

      $ErrorCode:=-15000

End case

$0:=$ErrorCode
```

I use this format for several reasons. The qualities to notice are:

The trigger always return a result through $0 even if no error is expected. This habit emphasizes that the trigger is a function and makes it easy to add error results later.

All possible and *impossible* database events are tested. This testing makes it explicit that each possibility has been considered, not neglected.

Each event calls a subroutines instead of putting the functional code directly in the trigger.

The subroutine calls surprise some people, so I will add a few comments. I believe that using project methods for the "guts" of your triggers provides these benefits:

1) The trigger is small and loads quickly. Only the code for the current database event is loaded.
2) It makes it easy for two events to call the same routine, like both of the save events above.
3) It makes it easy for different tables to share code.
4) The function of the trigger is clear: it is a dispatcher.

The last advantage is part of a programming philosophy that deservers thinking about, even if you don't follow it all the time.

One Routine: One Task

Many programmers believe that a routine should do one thing, and one thing only. This delivers several benefits:

✓ Routine names are completely descriptive. If you cannot create a clear name, chances are the routine does more than one thing. If you can understand what a routine does by reading its name, you do not have to open it up. This makes the code in your program easier to master. If a routine does several things, you have to read its code to figure out what is going on. This makes the program more time consuming to understand.

✓ It is easier to reuse code since it is broken down into small, well-defined units.

✓ Individual routines tend to be smaller. This promotes code that loads quickly, and is often easier to edit. I am not suggestion that short routines are always better. If a routine needs to be long to get the job done, then it should be long.

If you follow this rule, what do you do about triggers? The same trigger runs for any database event, meaning that one trigger can do any of four things. Are you saving a new record? Modifying an existing record? Deleting a record? All these actions have in common is that they change data. In practice, it is normal to have some routines that choose between several possible actions and perform one of them. The solution is to see that there are two kinds of routines and not to mix the two:

Functional routines perform a task.

Dispatching routines call functional routines.

Dispatching routines are called "dispatchers" or "transaction centers" depending who you talk with or read. I prefer the term dispatchers because it is descriptive and accurate. Dispatching routines should be rare in a 4D database, but they are a natural way to structure triggers. So, triggers are dispatchers that call the functional routines needed for the current database event.

Error Handling

Overview

If you use triggers, you need to include error handlers. Triggers give you a chance to stop operations that should not take place. Triggers return a longint result in $0. If you return a 0, this says “the operation was fine” and the requested operation (save or delete) is committed. If you return an error code, then the requested operation does not take place. In order for this to work correctly, you should always install a custom error handler with **ON ERR CALL** to trap and handle trigger errors. When you receive one of your custom errors you can give the user guidance on how to correct the problem.

4D Versus 4D Server

In every version of 4D I have tested error handling for the same trigger differs when deployed under 4D and 4D Server. If you are going to deploy under 4D Server, you should do the following:

- ❖ Test under 4D Server.
- ❖ Test under 4D Server.
- ❖ Test under 4D Server.
- ❖ Install a custom error handler on the client side with **ON ERR CALL**.
- ❖ Install a custom error handler on the server side with **ON ERR CALL**.

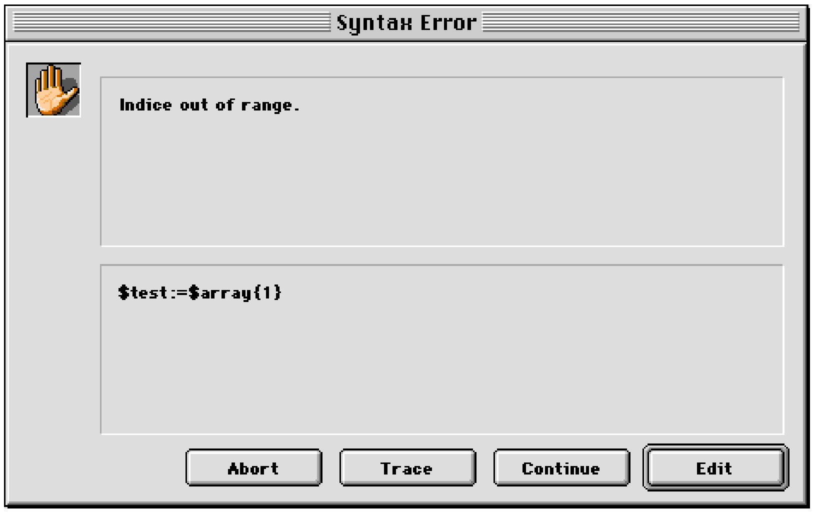
Do not consider trying to save time by avoiding any of these steps as you will almost certainly end up with errors which take even more time to correct.

Why You Need a Server-Side ON ERR CALL Method

A custom error method installed on the server machine from inside a trigger traps code errors and allows you to detect errors in a trigger cascade. Imagine, for example, that you have a trigger that includes this code:

```
ARRAY LONGINT($array;0)
$test:=$array{1}
```

This code produces a range error because it asks 4D to read an array element that does not exist:


Indice out of range.

$test:=$array{1}

Not what you want to see on the server machine.

Think about what happens if this dialog appears on the server machine. It means that the current trigger is halted, and that the requesting process is halted while waiting for the dialog to be dismissed. The problem is not limited to the current user: it spreads to any other process that invokes a trigger. Only one trigger executes at a time globally, so an error like this stops more and more clients as they perform work that invokes triggers. Since their triggers are waiting in line behind the stalled trigger, their process appears frozen. This looks particularly odd because other processes continue to run…until they invoke a trigger. Ideally you should remove all such errors from your code, but an **ON ERR CALL** routine lets you trap and handle the error without delaying the trigger indefinitely.

You also need to use a custom error handler inside a server side trigger to detect errors from a trigger cascade.

[Building] trigger invokes [Room] trigger.

[Room] trigger returns an error.

How does the [Building] trigger read the error returned from the [Room] trigger? It reads the 4D system variable called Error. In my tests the Error system variable is populated reliably only if you have a custom error handler installed.

Installing Server Side Error Methods

All triggers and several database methods share a process variable table and a current error method. The most straightforward way to handle errors on the server is to install one error handling method in **On Server Startup**. If you are performing interpreted testing, you should also initialize the Error system variable:

```
Error:=0
ON ERR CALL("trapErrorsOnServer")
```

Trigger Optimization

Keep Triggers Short and Fast

It is rarely sensible to worry about the small speed differences between similar lines of code. Micro-optimization almost never pays for itself. Trigger code is one place where the small things have a chance to add up into noticeable performance differences. Your trigger code should include whatever is required and nothing else. The following phrase should be your guide for trigger construction:

Honor sufficiency.

Because triggers run often—and only one runs at a time—a slow trigger can cause noticeable performance problems. Do not read this to mean "triggers are slow" or "triggers make your system slow". Triggers are a powerful feature and execute quickly. The point of this discussion is to emphasize that triggers are designed for certain tasks, and you should use them appropriately. If you use them as designed and as intended, you will be happy with them.

Avoid The On Load Trigger

There are three reasons that you should avoid the Load Record Event database event:

1) It slows everything down.
2) You probably don't need it.
3) It doesn't work anyway.

The Load Record Event database runs once for *each* record loaded in a selection. This means it runs once for each record displayed in an output form. Under 4D Server, the trigger runs on the server machine. So a long trigger, executed for each record at an output form on a single client machine, reduces the server processing time available to *all* other processes and clients. Because triggers can run frequently, it is essential that you make sure that only the events you use are turned on in the table properties dialog, and that your trigger code executes quickly and is error free.

You probably don't need the Load Record Event database event anyway. Loading a record is not a data modification event. Apart from tables that must have each loading recorded for detailed auditing there is no appropriate use for this event. Interface related operations and initialization are not appropriate for a trigger. Remember, triggers enforce rules about data.

The Load Record Event database event does not always run for performance reasons. 4D and 4D Server optimize performance by using field indexes rather than loading entire records. This is a good thing. The Load Record Event database event does not run unless the record is loaded. This means that common commands like **QUERY** do not invoke the Load Record Event database event for each record in the selection. According to ACI's documentation, it is difficult to determine when this event will or will not be invoked reliably.

Triggers and Transactions

Rules

You cannot start or stop transactions inside of triggers. Doing so could change the current record, which is a forbidden action during the record commit period. Transactions must be managed by the invoking process. In other words, if a trigger performs actions that may need to be rolled back, the trigger must already be in a transaction stared by the client machine. Your triggers can test if a transaction has already started with the **In transaction** function. Here is an outline of how triggers and transactions fit together:

```
Start transaction on from invoking process.

   Trigger and all cascaded triggers run on database engine machine.
   Trigger returns an error code or 0 for no error.

If (There was no error in the triggers)

   Validate transaction from invoking process.

Else

   Cancel transaction from invoking process.

End if
```

I say “invoking” process instead of “client machine” because the invoking process can legitimately be any of the following:

- ❖ A global process under 4D.
- ❖ A Web process under 4D.
- ❖ A global process under 4D Client.
- ❖ A Web process under 4D Client.
- ❖ A stored procedure under 4D Server.

The point is that the trigger (or trigger cascade) is wrapped inside of a transaction but does not manage the transaction itself. The invoking process uses the result returned by the trigger to determine if the transaction should be validated.

Automatic Action Buttons

You can use automatic action buttons that invoke triggers (accept, delete, first, previous, next and last record), only if the button object methods do not contain transaction management code.

When a coded automatic action button is clicked, the object method code executes first, then the trigger is invoked. So, if the input form is executing in a transaction, the transaction must be managed in the button method, which means the transaction is validated/cancelled before the trigger runs. This is a significant problem.

If, for instance, you were to execute **VALIDATE TRANSACTION** in the method of an automatic action next record button, the transaction would be validated before the trigger runs, meaning that the trigger’s actions take place outside of the transaction and cannot be rolled back. This creates serious data integrity problems if the trigger encounters a locked record it needs to modify or for any other reason, it cannot execute successfully. The calling process has already validated the transaction before the trigger has determined if the user can leave the form!

In order to avoid this situation you must refrain from using automatic action buttons on forms that execute in transactions and invoke triggers. Instead, you should use coded no-action buttons. In the button method execute **SAVE RECORD** first, which causes the trigger to run. If the trigger returns an error, **SAVE RECORD** is blocked by 4D and the subsequent object method code can react to the error appropriately. Here is an example of a simple no action next record button method that can be used if the form executes in a transaction:

```
` This causes the trigger to run and display an alert if there is an error.
SAVE RECORD([Table1])

If (Error=0)  ` If the trigger succeeds...
   VALIDATE TRANSACTION
   NEXT RECORD([Table1])  ` Go to the next record.
End if
```

Record Management Under 4D Server

Record Locking With a Twist

4D/4D Server automatically manage record locking for you. When one process has a record loaded for editing, no other process can load the record for editing at the same time. Any number of processes and clients can view the record, but only one can change it. Triggers under 4D Server add a new twist to record locking: the server machine and the client machine share read-write access to the same record. This means that code on two different machines can edit the same record. This is how a trigger should work, but there are some gotchas and side-effects to think about. After a review of how 4D manages records, we will look at the implications for triggers.

Copies of Records

Normally 4D spares your from thinking about how records are managed at a low level. To master how triggers work under 4D Server you need to understand how 4D manages records modifications. When you're working in 4D and you load a record what does 4D do?

1) 4D checks if the table is in read-write state.
2) 4D checks if the record is locked.
3) 4D loads a copy of the record into RAM.
4) 4D locks the record if appropriate.

You are working with a *copy* of the record from the data file. When you modify a record in code or in a form, you are changing the copy of the record in memory, not the copy in the data file. Once you save the record, the copy in memory is written back to the record cache, and eventually to the data file. If you examine the value of a record you have modified in the current process, you see whatever values you have assigned, not the values saved in the data file. Any other user or process looking at the record sees the last saved copy. When you use triggers under 4D Server, you need to keep in mind how records work because it is possible to load copies of the record on the server machine and the client machine. Here is what happens when you load a record under 4D Client:

1) 4D Server checks if the table is in read-write state.
2) 4D Server checks if the record is locked.
3) 4D Server loads a copy of the record and transfers it to the Client machine.
4) 4D Server locks the record if appropriate.

The current copy is on the client machine. The current record is selected but not always loaded into memory on the server machine. What happens when you save a record from 4D Client?

1) 4D Client sends the modified record to 4D Server.
2) 4D Server makes these values the current values for the record. (As a side effect, the **Old** function doesn't work inside of triggers under some versions of 4D Server.)
3) If there is a trigger, 4D Server runs the trigger. You can modify the record.
4) 4D Server saves all of the changes to the data file.

In other words, your client changes are saved, and then any additional trigger based changes are also saved. This is exactly what should happen. Prior to 4D Server 6.0.5 there was one problem: trigger based changes were not reloaded automatically on the client machine. The client machine still had the copy of the record it sent to the server machine. This means that the client copy did not include any changes made by the trigger. The copy in the data file was correct, but the client did not have it. This means that if the client saves additional changes, (with its now out of date copy of the record) the previous trigger-made changes were lost. Since the client never reloaded the record, the work of earlier triggers is gone. Let's look at how this works with an example. Imagine you have a database of US addresses. The table's trigger enforces two rules:

1) State abbreviations are must be in upper case.
2) Every modification is logged in a text field.

Let's look at what happens when a customer moves from Washington state (WA) to California (CA).

Action	Value In Data File	Vale On Client Machine	Value On Server Machine
LOAD RECORD	WA 5/5/98 10:00:00	WA 5/5/98 10:00:00	*No copy loaded.*
Change value on client machine	WA 5/5/98 10:00:00	ca 5/5/98 10:00:00	*No copy loaded.*
SAVE RECORD	WA 5/5/98 10:00:00	ca 5/5/98 10:00:00	*No copy loaded*
The trigger runs	WA 5/5/98 10:00:00	ca 5/5/98 10:00:00	CA 5/7/98 11:23:16 5/5/98 10:00:00
The record is saved	CA 5/7/98 11:23:16 5/5/98 10:00:00	ca 5/5/98 10:00:00	CA 5/7/98 11:23:16 5/5/98 10:00:00

The data file has the right value, but the client has the old values. The state field is not capitalized, and the modification history doesn't include the latest changes. If the client modifies and saves the record again the previous time stamp is lost. Because of this gotcha, 4D Server 6.0.5 and later automatically reload the record on the client after saving. An additional step is added to the table above:

Action	Value In Data File	Vale On Client Machine	Value On Server Machine
The record is reloaded	CA 5/7/98 11:23:16 5/5/98 10:00:00	CA 5/7/98 11:23:16 5/5/98 10:00:00	CA 5/7/98 11:23:16 5/5/98 10:00:00

The entire record is sent to the server machine and then sent back to the client. This results in extra network traffic but is the only way to insure that your data is accurate in all cases.

Server Side Changes

4D Server 6.0.5 and later avoid the obvious problems of losing trigger-based changes when you save a record from the client. You can do this yourself in earlier versions by issuing a **LOAD RECORD** after **SAVE RECORD**. You still need to reload records explicitly when the modifications and saves are performed entirely in the trigger. Imagine that your Customer trigger looks like this:

```
Case of
   : (Database event=Save Existing Record Event)
       ` Make sure that the state is all uppercase:
       [Customer]State:=Uppercase([Customer]State)

       ` Add to the time stamp text field:
       $strTimeStamp:=String(Current date)+" "+String(Current time)
       [Customer]ModificationHistory:=$strTimeStamp+Char(Carriage return)+
       [Customer]ModificationHistory

       ` Update and save the current message record:
   LOAD RECORD([TriggerMessage])
   [TriggerMessage]Message:="Updating value on the server machine."
   SAVE RECORD([TriggerMessage])

End case
```

The [TriggerMessage] record is updated in the data file, but the client does not have a copy of the changes. This is because the modification and save were performed entirely on the server machine. (This situation should occur rarely, if at all, in your systems.) Here is how the client would get a current copy of the record:

```
       ` 4D Client will automatically reload this record,
       ` including whatever changes were made in the trigger.
SAVE RECORD([Customer])

       ` The [Customer] trigger updates a value in the
       ` current record in [TriggerMessage]. These
       ` changes will not be reloaded automatically.
       ` Call LOAD RECORD to get a fresh copy on the client machine:
LOAD RECORD([TriggerMessage])
```

Huh?

If all this seems a little confusing, well it is! The code you have just seen is inherently difficult to read. You can not know what is going on (or what isn't working right) without understanding the trigger's code and where it executes. **SAVE RECORD** calls an implicit subroutine that you cannot see. This behavior is invisible when you look at the code itself. The benefits triggers provide offset this difficulty, but the difficulty remains. It is to your advantage to make your trigger code as straightforward as possible to reduce errors and increase readability. If you need to explicitly reload records on the client machine, examine your design critically to see if there is a more straightforward approach.

Now let's take a look at a technique that relies on server-side record modifications and client-side record reloading. This example illustrates how to write this kind of code if you determine you need it.

Returning Extra Information From the Trigger

Introduction

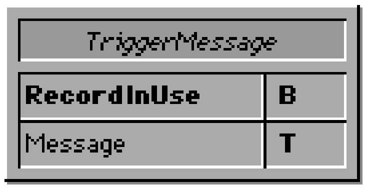
Triggers are designed to return a result to the client through $0. You can define your own error codes in the range from -15,000 to -32,000. This range of custom error codes should be sufficient to identify the error and give the client guidance about the problem. Some developers like to return additional information from a trigger describing the problem in more detail. If, for example, a cascading delete cannot be finished, it is helpful to know which file prevented the deletion. One approach is to define unique error codes for each table, another is to return extra information. Unique error codes are reliable and easy to implement. You can pass extra information between a client process and a trigger through a utility record, but think carefully before implementing this design.

Use a Record

4D Server allows client machines to read process and interprocess variables from the server machine. This would appear to be the natural way to prepare extra information for the client to read. Records are a superior approach for these reasons:

> Using variables for inter-workstation communication takes special object locking code.
>
> All triggers share a common set of process variables, so using them for communication with a specific client takes special coding that can become bottlenecks.
>
> Some client types (ODBC, 4D Open) cannot read 4D Server variables directly, but they can read records.
>
> I do not like variable to variable interprocess communication in general. Having one process reach directly inside another process is a practice that lends itself to creating buggy systems.

A two field table structure to allow a trigger to write extra information for a client to read, or for a client to write for a trigger to read:



TriggerMessage	
RecordInUse	B
Message	T

A text field stores the message.

Here is an outline of how the table is used. This is split into two columns to emphasize where each action takes place.

Invoking Process	Trigger on 4D Server Machine
Start transaction.	
Create or reuse an available [TriggerMessage] record.	
Perform action that invokes trigger.	Run trigger.
	Update [TriggerMessage] record with whatever information you want to provide to the invoking process.
	Save the updated [TriggerMessage] record.
Reload the [TriggerMessage] record.	
Display the message to the user.	
Cancel or validate the transaction.	

The key to this technique is that the invoking process explicitly loads a fresh copy of the [TriggerMessage] record after the trigger runs. This is an application of the information about records and copies of records discussed already. If you want to cancel or validate the transaction before displaying a message to the user, I suggest copying the message data into a local variable.

If you cancel the transaction in the steps outlined above, the client still has a copy of the [TriggerMessage] record. If you look in the debugger, you will see that the table has a selection of 0 records, and that there are field values for a record! This is another implication of record copying. I suggest you not rely on this behavior because it is undocumented and counterintuitive for many.

Restrictions on Your Code In Triggers

Do Not Change the Current Record Or Current Selection

Triggers run when a data modification is about to happen. It is a delicate moment between the time a change is requested, and the database is actually updated. This is the "record commit phase". During the record commit phase 4D has a copy of your record in memory ready for saving or deleting. You can reject an event entirely (like stopping a delete) by returning an error code in $0. You *must not* do anything inside the trigger that changes the current record, the current selection of the current table, or any table earlier in the current trigger cascade. Here is a list of commands to avoid:

Commands you cannot apply to any table in the current trigger cascade.

ALL RECORDS	ARRAY TO SELECTION
Before selection	CREATE RELATED ONE
DELETE RECORD	DISTINCT VALUES
End selection	EXPORT DIF
EXPORT TEXT	GOTO RECORD
IMPORT DIF	LAST RECORD
LOCKED ATTRIBUTES	Min
OLD RELATED MANY	ONE RECORD SELECT
ORDER BY FORMULA	PREVIOUS RECORD
QUERY	QUERY SELECTION
READ ONLY	READ WRITE
Records in selection	RELATE MANY
RELATE ONE	SAVE OLD RELATED ONE
SAVE RELATED ONE	Std deviation
Sum squares	USE NAMED SELECTION
Variance	APPLY TO SELECTION
Average	CREATE RECORD
CUT NAMED SELECTION	DELETE SELECTION
DUPLICATE RECORD	FIRST RECORD
EXPORT SYLK	IMPORT TEXT
GOTO SELECTED RECORD	IMPORT SYLK
LOAD RECORD	Max
NEXT RECORD	OLD RELATED ONE
ORDER BY	POP RECORD
PUSH RECORD	QUERY BY FORMULA
QUERY SELECTION BY FORMULA	Read only state
RECEIVE RECORD	REDUCE SELECTION
RELATE MANY SELECTION	RELATE ONE SELECTION
SAVE RECORD	SCAN INDEX
Sum	UNLOAD RECORD
USE SET	

Command restriction information provided by ACI.

To help you avoid calling the wrong commands, the sample code includes a function called *tableLevelInCascade*. This function takes a table pointer and returns that table's current trigger level, or 0 if it is not in the current cascade.

More Comments on Not Changing The Current Record or Selection

For years the restriction on what you can do in the **After** phase (4D V3) or a trigger has been described as "you must not change the current record of the current table". If you heard this rule, and you are like most people, you wondered why many of these commands are forbidden. Why can't you execute **SAVE RECORD**, for example? (Well, for one thing, it might cause an endless loop if you used it in a trigger. Saving the record would call the trigger, which would call the trigger, which would call the trigger...) If you watch the current record with the debugger, you will see that the current record does not appear to change when you execute many of the commands in the table of forbidden commands. So why are they forbidden? This is why we spent time earlier discussing how 4D/4D Server works with records and copies of records. The restriction is better described as "you must not change the current record or force 4D to load a fresh copy of the current record." **SAVE RECORD**, and many of the other commands listed above reload the current record as part of their behavior. Some commands reload an automatically related one record when applied to a many table, which is why they cannot be used inside of certain trigger cascades.

Other Command Limits

Several commands have limited use within triggers or potentially create performance problems:

Commands with limited use in triggers.

Command	Limit
BLOB TO DOCUMENT	Usable but to be avoided for performance reasons.
DOCUMENT TO BLOB	Usable but to be avoided for performance reasons.
EXECUTE	Allowed, but you should not use any of the forbidden commands.
PAUSE PROCESS	Do not use on the current process.
SELECTION RANGE TO ARRAY	Usable but to be avoided for performance reasons.
SELECTION TO ARRAY	Usable but to be avoided for performance reasons.
SET CHANNEL	Usable for file operations but not for modem operations.
Open window	Do not use interface commands on the server machine.
ALERT	Do not use interface commands on the server machine.
CONFIRM	Do not use interface commands on the server machine.
DIALOG	Do not use interface commands on the server machine.
MESSAGE	Do not use interface commands on the server machine.
Request	Do not use interface commands on the server machine.

Remember that only one trigger executes at a time, so a slow operation could be noticed by several users. You should not open windows of any kind as they appear on the server machine where the user may not be able to reach them. You may use the **TRACE** command during development if you have access to the server machine.

Trigger Development Worksheet

Complete one copy of this form for each trigger event in each table.

Database Name	
Table Name	
Trigger (*Check one*)	☐ **Loading a record** ☐ **Saving a new record** ☐ **Saving an existing record** ☐ **Deleting a record**
Method Name	
Action(s)	
Error Codes *Include descriptions*	