

# The ABEL Persistence Library Tutorial

Roman Schmocker, Marco Piccioni

Last updated:

August 1, 2012

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# Chapter 1

## Introducing ABEL

ABEL (A Better EiffelStore Library) is an object-oriented persistence library written in Eiffel and aiming at seamlessly integrating various kinds of data stores.

### 1.1 Setting things up

We are assuming you have checked out the ABEL code from the EiffelStudio SVN repository<sup>1</sup>, and have EiffelStudio installed. Launch it and in the initial window choose "tutorial\_project". If it is not there just push "Add project" and navigate to the location where you downloaded ABEL, and look for the *tutorial\_project.ecf* project file in *abel/apps/sample/tutorial/*. You can then load and compile the project. To be able to compile the ABEL tutorial you don't need particular dependencies, because we are using an in-memory database simulating a relational database. If you want to experiment with ABEL's support for full-fledged relational back-ends (like MySQL or SQLite), you need to install the databases and the appropriate drivers first.

### 1.2 Getting started

We will be using *PERSON* objects to show the usage of the API. In the source code below you will see that ABEL handles objects "as they are", meaning that to make them persistent you don't need to add any dependencies to their class source code.

---

<sup>1</sup><https://svn.eiffel.com/eiffelstudio/branches/eth/eve/Src/library/abel>

```

class PERSON

3 create
    make

6 feature {NONE} -- Initialization

    make (first, last: STRING)
9    -- Create a newborn person.
    require
        first_exists: not first.is_empty
12    last_exists: not last.is_empty
    do
        first_name := first
15    last_name := last
        age := 0
    ensure
18    first_name_set: first_name = first
        last_name_set: last_name = last
        default_age: age = 0
21 end

feature -- Basic operations
24
    celebrate_birthday
        -- Increase age by 1.
27    do
        age := age + 1
    ensure
30    age_incremented_by_one: age = old age + 1
end

33 feature -- Access

    first_name: STRING
36    -- The person's first name.

    last_name: STRING
39    -- The person's last name.

    age: INTEGER
42    -- The person's age.

```

```

invariant
45  age_non_negative: age >= 0
    first_name_exists: not first_name.is_empty
    last_name_exists: not last_name.is_empty
48 end

```

**Listing 1.1:** The *PERSON* class

There are three very important classes in ABEL:

- The deferred class *PS\_REPOSITORY* provides an abstraction to the actual storage mechanism.
- The *PS\_CRUD\_EXECUTOR* class is, as the name suggests, responsible to execute CRUD (Create Read Update Delete) commands. Every *PS\_CRUD\_EXECUTOR* object works with a *PS\_REPOSITORY*.
- The *PS\_OBJECT\_QUERY* [*G*] class is used to describe a read operation over objects of type *G*. You can execute such a query in the *PS\_CRUD\_EXECUTOR*. The result will be objects of type *G*.

To start using the library, we first need to create an object of type *PS\_REPOSITORY*. In this case we will be creating a more specific object of type *PS\_IN\_MEMORY\_REPOSITORY*. More in general, ABEL provides support for creating *PS\_RELATIONAL\_REPOSITORY* objects with the factory class *PS\_REPOSITORY\_FACTORY*.

As a second step, we need to create an object of type *PS\_CRUD\_EXECUTOR*. To do so, we will pass the previously created repository as an argument to its creation feature.

```

class TUTORIAL

3  create
    make

6  feature {NONE} -- Initialization

    make

9  -- Set up a simple in-memory repository.
    local
        repository: PS_IN_MEMORY_REPOSITORY
12  do
        create repository.make_empty
        create executor.make (repository)
15  end

```

```
feature
18   executor: PS_CRUD_EXECUTOR
      -- The CRUD executor used throughout the tutorial.
21 end
```

***Listing 1.2: The TUTORIAL class***

We will use this class throughout the tutorial. You can assume that the Eiffel features listed in this tutorial are located inside the *TUTORIAL* class, if they are not enclosed in another class declaration.

We encourage you to test the features shown in this tutorial by calling them from feature *explore* in class *TUTORIAL*.

# Chapter 2

## Basic operations

### 2.1 Inserting

You insert an object in the repository using feature *insert* in class *PS\_CRUD\_EXECUTOR*. Let's add three new persons to the database in feature *explore*:

```
explore
  -- Tutorial code.
3  local
    p1, p2, p3: PERSON
  do
6    -- Insert 3 new persons in the database
    create p1.make ("Albo", "Bitossi")
    p1.celebrate_birthday
9    executor.insert (p1)
    create p2.make ("Berno", "Citrini")
    p2.celebrate_birthday
12   p2.celebrate_birthday
    p2.celebrate_birthday
    executor.insert (p2)
15   create p3.make ("Dumbo", "Ermini")
    executor.insert (p3)
  end
```

*Listing 2.1: Insertion code.*

## 2.2 Querying

A query for objects is done by creating a `PS_OBJECT_QUERY [G]` object and executing it using features of `PS_CRUD_EXECUTOR`. The generic parameter `G` denotes the type of objects that should be queried.

After a successful execution of the query, you can find the result in the iteration cursor `result_cursor` in class `PS_OBJECT_QUERY`. The feature `simple_query` below shows how to get a list of persons from the repository:

```
simple_query: LINKED_LIST [PERSON]
-- Query all persons from the current repository.
3  local
    query: PS_OBJECT_QUERY [PERSON]
  do
6    create Result.make
    create query.make
    executor.execute_query (query)
9
    across query as query_result
  loop
12   Result.extend (query_result.item)
  end
end
```

**Listing 2.2:** A simple query.

We now add in feature `explore` the code to print the linked list returned by feature `simple_query`:

```
explore
-- Tutorial code.
3  local
    p1, p2: PERSON
  do
6    -- Same code as before
    -- Query the database and print result
    print_result (simple_query)
9  end
```

**Listing 2.3:** Printing the query result.

Feature `print_result` takes the linked list result of the query and prints all its elements. Usually the result of such a query is very big, and you are probably only interested in objects that meet certain criteria, e.g. all persons of age 20. You can read more about it in Chapter 3.



Please note that ABEL does not enforce any kind of order on a query result.

## 2.3 Updating

Updating an object is done through feature *update* in *PS\_CRUD\_EXECUTOR*. Let's update the *age* attribute of Berno Citrini by celebrating his birthday:

```
explore
  -- Tutorial code.
3  local
    p1, p2: PERSON
  do
6    -- Same code as before
    -- Update an existing person in the database and print
      the result again
    p2.celebrate_birthday
9    executor.update (p2)
    print_result (simple_query)
  end
```

*Listing 2.4: Printing the query result.*

The object to update needs to be previously known to ABEL through an insert or a successful query (see Section 2.5).

## 2.4 Deleting

Deletion is done through feature *delete* in *PS\_CRUD\_EXECUTOR*. Let's now delete Albo Bitossi from the database:

```
explore
  -- Tutorial code.
3  local
    p1, p2: PERSON
  do
6    -- Same code as before
    -- Delete Dumbo Ermini from the database and print the
      result again
    executor.delete (p3)
9    print_result (simple_query)
  end
```

*Listing 2.5: Deleting an object.*

The object to delete needs to be previously known to ABEL through an insert or a successful query (see Section 2.5). A way to delete objects that always works (because ABEL queries for them in advance) is described in Section 3.3.

## 2.5 Dealing with Known Objects

ABEL keeps track of objects that have been inserted or queried. This is important because in case of an update or delete, the library internally needs to map the object in the current execution of the program to its specific entry in the database.

Because of that, you can't update or delete an object that is not yet known to ABEL. As an example, the following two functions will fail:

```

failing_update
2  -- Try and fail to update a new person object
   local
     a_person: PERSON
5  do
     create a_person.make ("Bob", "Barath")
     executor.update (a_person)
8     -- Results in a precondition violation
   end

11 failing_delete
   -- Try and fail to delete a new person object
   local
14   a_person:PERSON
   do
     create a_person.make ("Cersei", "Lannis")
17   executor.delete (a_person)
     -- Results in a precondition violation
   end
```

*Listing 2.6: Failing updates and deletes.*

Please note that there's another way to delete objects, described in Section 3.3, which doesn't have this restriction.

The feature *is\_persistent* in *PS\_CRUD\_EXECUTOR* can tell you if a specific object is known to ABEL and hence has a link to its entry in the database.

# Chapter 3

## Advanced Queries

### 3.1 The query mechanism

As you already know from Section 2.2, queries to a database are done by creating an object of type *PS\_OBJECT\_QUERY[G]* and using it from within a *PS\_CRUD\_EXECUTOR*. The actual value of the generic parameter *G* determines the type of the objects that will be returned, including any conforming type (e.g. descendants of *G*).

ABEL will by default load an object completely, meaning all objects that can be reached by following references will be loaded as well (see also Chapter 4).

### 3.2 Criteria

You can filter your query results by setting criteria in the query object, using feature *set\_criteria* in *PS\_OBJECT\_QUERY*. There are two types of criteria: predefined and agent criteria.

#### 3.2.1 Predefined Criteria

When using a predefined criterion you pick an attribute name, an operator and a value. During a read operation, ABEL checks the attribute value of the freshly retrieved object against the value set in the criterion, and filters away objects that don't satisfy the criterion.

Most of the supported operators are pretty self-describing (see class *CRITERION\_FACTORY* in Section 3.2.3). An exception could be the **like** operator, which does pattern-matching on strings. You can provide the **like** operator with a pattern as a value. The pattern can contain the wildcard

characters \* and ?. The asterisk stands for any number (including zero) of undefined characters, and the question mark means exactly one undefined character.

You can only use attributes that are strings or numbers, but not every type of attribute supports every other operator. Valid combinations for each type are:

- Strings: =, like
- Any numeric value: =, <, <=, >, >=
- Booleans: =

Note that for performance reasons it is usually better to use predefined criteria, because they can be compiled to SQL and hence the result can be filtered in the database.

### 3.2.2 Agent Criteria

An agent criterion will filter the objects according to the result of an agent applied to them.

The criterion is initialized with an agent of type *PREDICATE* [*ANY*, *TUPLE* [*ANY*]]. There should be either an open target or a single open argument, and the type of the objects in the query result should conform to the agent's open operand. For an example see Section 3.2.3.

### 3.2.3 Creating criteria objects

The criteria instances are best created using the *CRITERION\_FACTORY* class.

The main features of the class are the following:

```

class
  PS_CRITERION_FACTORY
3 create
  default_create

6 feature -- Creating a criterion

  new alias "[]" (tuple: TUPLE [ANY]): PS_CRITERION
9   -- Creates a new criterion according to a 'tuple'
   -- containing either a single PREDICATE or three
   -- values of type [STRING, STRING, ANY].
12
```

```

    new_agent (a_predicate: PREDICATE [ANY, TUPLE [ANY]]):
        PS_CRITERION
        -- Creates an agent criterion.
15
    new_predefined (object_attribute: STRING;
        operator: STRING; value: ANY): PS_CRITERION
18    -- Creates a predefined criterion.

feature -- Operators
21
    equals: STRING = "="

24    greater: STRING = ">"

    greater_equal: STRING = ">="
27
    less: STRING = "<"

30    less_equal: STRING = "<="

    like_string: STRING = "like"
33
end

```

**Listing 3.1:** The *CRITERION\_FACTORY* class interface

Assuming you have an object *f*: *PS\_CRITERION\_FACTORY*, to create a new criterion you have two possibilities:

- The “traditional” way
  - *f.new\_agent* (**agent** *an\_agent*)
  - *f.new\_predefined* (*an\_attr\_name*, *an\_operator*, *a\_val*)
- The “syntactic sugared” way
  - *f*[[*an\_attr\_name*, *an\_operator*, *a\_value*]]
  - *f*[[**agent** *an\_agent*]]

caption=The *CRITERION\_FACTORY* interface

```

    create_criteria_traditional : PS_CRITERION
3    -- Create a new criteria using the traditional approach.

```

```

do
  -- for predefined criteria
6   Result :=
      factory.new_predefined ("age", factory.less, 5)

  -- for agent criteria
9   Result :=
      factory.new_agent (agent age_more_than (?, 5))
12 end

create_criteria_double_bracket : PS_CRITERION
15 -- Create a new criteria using the double bracket syntax
    .
do
  -- for predefined criteria
18   Result := factory[["age", factory.less, 5]]

  -- for agent criteria
21   Result := factory[[agent age_more_than (?, 5)]]
end

24 age_more_than (person: PERSON; age: INTEGER): BOOLEAN
    -- An example agent
do
27   Result := person.age > age
end

```

*Listing 3.2: Different ways of creating criteria.*

### 3.2.4 Combining criteria

You can combine multiple criterion objects by using the standard Eiffel logical operators. For example, if you want to search for a person called “Albo Bitossi” with *age* ≤ 20, you can just create a criterion object for each of the constraints and combine them:

```

1   composite_search_criterion : PS_CRITERION
    -- Combining criterion objects.
4   local
      first_name_criterion: PS_CRITERION
      last_name_criterion: PS_CRITERION
7   age_criterion: PS_CRITERION
do

```

```

first_name_criterion:=
10     factory[[ "first_name", factory.equals, "Albo" ]]

last_name_criterion :=
13     factory[[ "last_name", factory.equals, "Bitossi" ]]

age_criterion :=
16     factory[[ agent age_more_than (?, 20) ]]

Result := first_name_criterion and last_name_criterion
        and not age_criterion
19

-- using double brackets for compactness.
Result := factory[[ "first_name", "=", "Albo" ]]
22     and factory[[ "last_name", "=", "Bitossi" ]]
        and not factory[[ agent age_more_than (?, 20) ]]
end

```

*Listing 3.3: Combining criteria.*

ABEL supports the three standard logical operators **AND**, **OR** and **NOT**. The precedence rules are the same as in Eiffel, which means that **NOT** is stronger than **AND**, which in turn is stronger than **OR**.

We can now add the necessary code to feature *explore*:

```

explore
  -- Tutorial code.
3  local
    p1, p2: PERSON
  do
6    -- Same code as before
    -- Search for Albo Bitossi with age <= 20
    print_result (query_with_composite_criterion)
9  end

```

*Listing 3.4: Invoking the code that searches for Albo Bitossi*

Where feature *query\_with\_composite\_criterion* looks like the following:

```

query_with_composite_criterion: LINKED_LIST [PERSON]
  -- Query using a composite criterion.
3  local
    query: PS_OBJECT_QUERY [PERSON]
  do
6    create Result.make

```

```

    create query.make
    query.set_criterion (composite_search_criterion)
9    executor.execute_query (query)

    across query as query_result
12   loop
        Result.extend (query_result.item)
    end
15 end

```

*Listing 3.5: Invoking the code that searches for Albo Bitossi*

As you may have noticed, it is very simple to set criteria on a query.

### 3.3 Deletion queries

As mentioned in Section 2.4, there is another way to perform a deletion in the repository from within *PS\_CRUD\_EXECUTOR*. By calling *execute\_deletion\_query* instead of *delete*, ABEL will delete all objects in the database that would have been retrieved by executing the query normally.

```

delete_person_with_deletion_query (last_name: STRING)
-- Delete person with 'last_name' using a deletion query
.
3  local
    deletion_query: PS_OBJECT_QUERY [PERSON]
    criterion:PS_PREDEFINED_CRITERION
6  do
    create deletion_query.make
    create criterion.make ("last_name", "=", last_name)
9    deletion_query.set_criterion (criterion)
    executor.execute_deletion_query (deletion_query)
end

```

*Listing 3.6: Using a deletion query.*

We can now add the necessary code to feature *explore*:

```

explore
-- Tutorial code.
3  local
    p1, p2: PERSON
    do
6      -- Same code as before
      -- Delete Albo Bitossi using a deletion query

```



```
        delete_person_with_deletion_query ("Bitossi")
9      print_result (simple_query)
    end
```

**Listing 3.7:** *Invoking the code that searches for Albo Bitossi*

Using a deletion query instead of a direct delete command depends upon the situation. Usually, a direct command is better if you already have the object in memory, whereas deletion queries are nice to use if the object is not yet loaded from the database.

# Chapter 4

## Dealing with references

In ABEL, a basic type is an object of type *STRING*, *BOOLEAN*, *CHARACTER* or any numeric class like *REAL* or *INTEGER*. The *PERSON* class only has attributes of a basic type. However, an object can contain references to other objects. ABEL is able to handle these references by storing and re-constructing the whole object graph (an object graph is roughly defined as all the objects that can be reached by recursively following all references, starting at some root object).

### 4.1 Inserting objects with dependencies

Let's look at the new class *CHILD*:

```
class
3  CHILD

create
6  make

feature {NONE} -- Initialization
9
    make (first, last: STRING)
        -- Create a new child.
12  require
        first_exists: not first.is_empty
        last_exists: not last.is_empty
15  do
        first_name := first
        last_name := last
```

```

18     age := 0
    ensure
      first_name_set: first_name = first
21     last_name_set: last_name = last
      default_age: age = 0
    end
24
    feature -- Access

27    celebrate_birthday
      -- Increase age by 1.
    do
30      age := age + 1
    ensure
      age_incremented_by_one: age = old age + 1
33    end

    feature -- Status report

36      first_name: STRING
        -- The child's first name.
39
        last_name: STRING
        -- The child's last name.
42
        age: INTEGER
        -- The child's age.
45
    feature -- Parents

48    mother: detachable CHILD
      -- The child's mother.

51    father: detachable CHILD
      -- The child's father.

54    set_mother (a_mother: CHILD)
      -- Set a mother for the child.
    do
57      mother := a_mother
    ensure
      mother_set: mother = a_mother
60    end

```

```

    set_father (a_father: CHILD)
63     -- Set a father for the child.
    do
        father := a_father
66     ensure
        father_set: father = a_father
    end
69
    invariant
    age_non_negative: age >= 0
72    first_name_exists: not first_name.is_empty
    last_name_exists: not last_name.is_empty
end

```

**Listing 4.1:** The *CHILD* class.

This adds in some complexity: instead of having a single object, ABEL has to insert a *CHILD*'s mother and father as well, and it has to repeat this procedure if their parent attribute is also attached. The good news are that the examples above will work exactly the same.

However, there are some additional caveats to take into consideration. Let's consider a simple example with *CHILD* objects "Baby Doe", "John Doe" and "Grandpa Doe". From the name of the object instances you can already guess what the object graph looks like:



Now if you insert "Baby Doe", ABEL will by default follow all references and insert every single object along the object graph, which means that "John Doe" and "Grandpa Doe" will be inserted as well. This is usually the desired behavior, as objects are stored completely that way, but it also has some side effects we need to be aware of:

- Assume an insert of "Baby Doe" has happened to an empty database. If you now query the database for *CHILD* objects, it will return exactly the same object graph as above, but the query result will actually have three items, as the object graph consists of three single *CHILD* objects.
- After you've inserted "Baby Doe", it has no effect if you insert "John Doe" or "Grandpa Doe" afterwards, because they have already been inserted by the first statement.

Here is the code in feature *explore* that tests what we have stated above:

```
explore
  -- Tutorial code.
3  local
    p1, p2: PERSON
    c1, c2, c3: CHILD
6  do
    -- Same code as before
    print ("Insert 3 children in the database")
9    create c1.make ("Baby", "Doe")
    create c2.make ("John", "Doe")
    create c3.make ("Grandpa", "Doe")
12   c1.set_father (c2)
    c2.set_father (c3)
    executor.insert (c1)
15   io.new_line
    print ("Query the database for children and print
          result")
    print_children_result (query_for_children)
18   print ("Inserting John Doe has no effect")
    executor.insert (c2)
    print_children_result (query_for_children)
21 end
```

*Listing 4.2: Inserting objects having references to other objects.*

You can find the code for *query\_for\_children* and *print\_children\_result* in the ABEL repository. You will notice it is very similar to the corresponding routines seen before (the only thing that changes is the kind of linked list that is passed as an argument).

## 4.2 Updating objects with dependencies

ABEL does not follow references during an update by default, so for example the following statement has no effect on the database:

```
explore
  -- Tutorial code.
3  local
    p1, p2: PERSON
    c1, c2, c3: CHILD
6  do
```

```

-- Same code as before
print ("Updating John Doe has no effect")
9   if attached {CHILD} c1.father as dad then
    dad.celebrate_birthday
    end
12  executor.update (c1)
    print_children_result (query_for_children)
end

```

*Listing 4.3: References are not followed by default during updates.*

Section 4.3 will tell you how do change the default settings.

## 4.3 Going deeper in the Object Graph

ABEL has no limits regarding the depth of an object graph, and it will detect and handle reference cycles correctly. You are welcome to test ABEL's capability with very complex objects, however please keep in mind that this may impact performance significantly.

To overcome this problem, you can either use simple object structures, or you can tell ABEL to only load or store an object up to a certain depth. The default ABEL's behavior with respect to the object graph can be changed by using feature *default\_object\_graph* in class *PS\_REPOSITORY* and passing an appropriate object of type *PS\_DEFAULT\_OBJECT\_GRAPH\_SETTINGS*.

# Chapter 5

## Transaction handling

Every CRUD operation in ABEL is by default executed within a transaction. Transactions are created and committed implicitly. This is convenient when dealing with complex object graphs, because an object doesn't get inserted halfway in case of an error.

As a user, you also have the possibility to use transactions explicitly. This is done by manually creating an object of type *PS\_TRANSACTION* and using the *\*\_within\_transaction* features in *PS\_CRUD\_EXECUTOR* instead of the normal ones. For your convenience there is a factory method *new\_transaction* in class *PS\_CRUD\_EXECUTOR*.

Let's consider an example where you want to update the age of every person by one:

```
update_ages
-- Increase the age of all persons by one.
3  local
    query: PS_OBJECT_QUERY [PERSON]
    transaction: PS_TRANSACTION
6  do
    create query.make
    transaction := executor.new_transaction
9
    executor.execute_query_within_transaction (query,
        transaction)

12 across query as query_result
    loop
        query_result.item.celebrate_birthday
15    executor.update_within_transaction
        (query_result.item, transaction)
```

```

    end
18
    transaction.commit

21    -- The commit may have failed
    if transaction.has_error then
        if attached transaction.error.message as msg then
24            print ("Commit has failed. Error: " + msg)
        end
    end
27 end

```

You can see here that a commit can fail in some situations, e.g. when a write conflict happened in the database. The errors are reported in the `PS_TRANSACTION.has_error` attribute. In case of an error, all changes of the transaction are rolled back automatically.

You can also abort a transaction manually by calling feature `rollback` in class `PS_TRANSACTION`.

As usual, here is the code for feature `explore`:

```

explore
    -- Tutorial code.
3    local
        p1, p2: PERSON
        c1, c2, c3: CHILD
6    do
        -- Same code as before
        print ("Celebrating the birthday fo all PERSON objects
            in the repository")
9        update_ages
        print_result (simple_query)
    end

```

**Listing 5.1:** Testing an update with explicit transaction.

## 5.1 Transaction isolation levels

ABEL supports the four standard transaction isolation levels found in almost every database system:

- Read Uncommitted
- Read Committed



- Repeatable Read
- Serializable

The different levels are defined in `TRANSACTION_ISOLATION_LEVEL`. You can change the transaction isolation level by calling feature `set_transaction_isolation_level` in class `PS_REPOSITORY`. The default transaction isolation level of ABEL is defined by the actual storage backend.

Please note that not every backend supports all isolation levels. Therefore a backend can also use a more restrictive isolation level than you actually instruct it to use, but it is not allowed to use a less restrictive isolation level.

# Chapter 6

## Error handling

As ABEL is dealing with I/O and databases, runtime errors may happen. The library will in general raise an exception in case of an error and expose the error to the library user as an *PS\_ERROR* object. ABEL recognizes two different kinds of errors:

- Irrecoverable errors: fatal errors happening in scenarios like a dropped connection or a database integrity constraint violation. The default behavior is to rollback the current transaction and raise an exception. If you catch the exception in a rescue clause and manage to solve the problem, you can continue using ABEL.
- Recoverable errors: exceptional situations typically not visible to the user, because no exception is raised when they occur. An example is a conflict between two transactions. ABEL will detect the issue and, in case of implicit transaction management, retry. If you use explicit transaction management, ABEL will just doom the current transaction to fail at commit time.

ABEL maps database specific error messages to its own representation for errors, which is a hierarchy of classes rooted at *PS\_ERROR*. The following list shows all error classes that are currently defined.

If not explicitly stated otherwise, the errors in this lists belong to the first category (fatal errors).

- *CONNECTION\_PROBLEM*: A broken internet link, or a deleted serialization file.
- *TRANSACTION\_CONFLICT*: A write conflict between two transactions. This is a recoverable error.

- *UNRESOLVABLE\_TRANSACTION\_CONFLICT*: A write conflict between implicit transactions that doesn't resolve after a retry.
- *ACCESS\_RIGHT\_VIOLATION*: Insufficient privileges in database, or no write permission to serialization file.
- *VERSION\_MISMATCH*: The stored version of an object isn't compatible any more to the current type.
- *INTERNAL\_ERROR*: Any error happening inside the library, e.g. a wrong SQL compilation.
- *GENERAL\_ERROR*: Anything that doesn't fit into one of the categories above.

If you want to handle an error, you have to add a **rescue** clause somewhere in your code.

You can get the actual error from the feature *PS\_CRUD\_EXECUTOR.error* or *PS\_TRANSACTION.error* or - due to the fact that the *PS\_ERROR* class inherits from *DEVELOPER\_EXCEPTION* - by performing an object test on Eiffel's *EXCEPTION\_MANAGER.last\_exception*.

For your convenience, there is a visitor pattern for all ABEL error types. You can just implement the appropriate functions and use it for your error handling code.

The following code shows an example. Note that only relevant features are shown:

```

class
3  MY_PRIVATE_VISITOR
inherit
    PS_ERROR_VISITOR
6
feature
    shall_retry: BOOLEAN
9    -- Should my client retry the operation?

    visit_access_right_violation (
12    error: PS_ACCESS_RIGHT_VIOLATION)
        -- Visit an access right violation error.
    do
15        add_some_privileges
        shall_retry := True
    end

```

```

18      visit_connection_problem (error: PS_CONNECTION_PROBLEM)
        -- Visit a connection problem error.
21      do
          notify_user_of_abort
          shall_retry:=False
24      end
    end

27  class
    TUTORIAL

30  feature

    my_visitor: MY_PRIVATE_VISITOR
33    -- A user-defined visitor to react to an error.

    executor: PS_CRUD_EXECUTOR
36    -- The CRUD executor used throughout the tutorial.

39  do_something_with_error_handling
    -- Perform some operations. Deal with errors in case of
    a problem.
    do
42    -- Some complicated operations
    rescue
        my_visitor.visit (executor.last_error)
45    if my_visitor.shall_retry then
        retry
    else
48    -- The exception propagates upwards, and maybe
    -- another feature can handle it
    end
51  end
end

```

*Listing 6.1: Sample error handling using a visitor.*