20

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Creating objects

20.1 OVERVIEW

The dynamic model, whose major properties were explored in the preceding chapter, is highly flexible; your systems may create objects and attach them to entities at will, according to the demands of their execution. This chapter explores the two principal mechanisms for producing new objects: the Creation_instruction and its less frequently encountered sister, the Creation_expression.

A closely related mechanism — **cloning** — exists for duplicating objects. This will be studied in the next chapter together with the mechanism for copying the contents of an object onto another.

The creation constructs offer considerable flexibility, allowing you to rely on standard, language-defined initialization mechanisms for all the instances of a class, but also to override these defaults with your own conventions, to define any number of alternative initialization procedures, and to let each creation instruction provide specific values for the initialization. You can even instantiate an entity declared of a generic type — a non-trivial problem since, for *x* declared of type *G* in a class *C* [*G*], we don't know what actual type *G* denotes in any particular case, and how one creates and initializes instances of that type.

In using all these facilities, you should never forget the methodological rule governing creation:

> **Creation principle**
>
> Any execution of a creation operation should produce an object that satisfies the invariant of its generating class.

Such is the theoretical role of creation: to make sure that any object we create starts its life in a state satisfying the corresponding invariant. Many properties of creation, studied in this chapter, follow from this principle.

20.2 FORMS OF CREATION: AN OVERVIEW

You may use a Creation_instruction to produce a totally new object, initialize its variable fields to preset values, and attach it to a Writable entity called the **target** of the creation and named in the instruction.

The examples which follow assume that the target is of a reference (non-expanded) type. As will be seen below, the Creation_instruction is also applicable to expanded types, although with a less interesting effect.

See 20.8, page 428 below, about Creation instructions applied to expanded types.

Syntactically, a Creation_instruction always begins with the keyword **create**, followed by the target. Here are some examples:

The respective targets are account1, point1, account1, figure1.

```
[1]
    create account1
[2]
    create point1.make_polar (1, Pi / 4)
[3]
    create {SAVINGS_ACCOUNT} account1
[4]
    create {SEGMENT} figure1.make (point1, point2)
```

With form **1** you create an object of the type declared for *account1*, initialize it to default values, and attach it to *account1*. The default initialization is language-defined, although you can override it for any class.

With form **2** you create an object of the type declared for *point1*, apply the standard default initialization, complement the initialization by calling *make_polar* (a procedure of the class, designated as one of its "creation procedures") with the given arguments, and attach the object to *point1*.

Cases **3** and **4** are respectively similar to the first two, but specify an explicit type, in braces, for the newly created object. So if *account1* is of type *ACCOUNT*, form **1** creates an instance of that class, but form **3** creates an instance of *SAVINGS_ACCOUNT*. This requires *SAVINGS_ACCOUNT* to be a descendant of *ACCOUNT*. Similarly, in form **4**, *SEGMENT* must be a descendant of the type, say *FIGURE*, declared for *figure1*.

20.3 BASIC FORM

Even though example **1** shows the most concise variant, a better place to start studying the Creation_instruction is the more general variant illustrated by example **2**: **create** *x.creation_procedure* (…). Its effect is, in order, to:

1 • Create a new object — a direct instance of the type *T* of *x*.

2 • Initialize all the variable fields of that object to default values.

3 • Call *creation_procedure* on the object, with the arguments given, to complete its initialization.

4 • Attach *x* to the object.

The default initialization values used in step 2 are adapted to the type of each field corresponding to a variable attribute: zero for numbers, false for booleans, void for references and so on. The full rule will appear later.

→ *On the default initialization rule see 20.12, page 439.*

This form of the instruction is only valid if the base class *C* of *x*'s type *T* lists *creation_procedure* in its Creators part.

Such a Creators part is permitted only in an effective class (since it makes no sense to create direct instances of a deferred class). We have seen that it comes towards the beginning of a class text — just before Features but after Inheritance — and consists of at least one Creation_clause, each beginning with the keyword **create** followed by a list of zero or more procedures of the class, as in

← *"PARTS OF A CLASS TEXT", 4.7, page 61.*

```
class C … inherit
        …
create
        make, execute, …
feature
        …
end -- class C
```

where *make, execute* … are procedures of *C*. For the moment we are restricting ourselves to just one Creation_clause (the vast majority of cases). By including such a clause, the author of *C* specifies that any Creation_instruction producing direct instances of the class must be of one of the two forms

→ *You can use more than one* Creation_clause; *also, each one may restrict clients' creation privileges. See below "RESTRICTING CREATION AVAILABILITY", 20.7, page 425 for full details.*

```
create x.make (…)
create x.execute (…)
```

which will initialize the new object by calling the specified creation procedure — with actual arguments whose types and number match those of the formal arguments declared for the procedure.

The two creation-related constructs, Creators and Creation_instruction, both use the same keyword **create**. This makes things easier to remember than if you had to learn two keywords. No confusion can result since the constructs appear in completely different syntactic contexts.

Creation procedures (also known as "*constructors*" from C++ terminology) serve to apply initializations beyond the default ones if these do not suffice. For example, the author of a class *POINT* in a graphics system may wish to offer a creation mechanism that not only allocates a new object but also initializes its fields according to coordinates provided by the client. Here is an outline of such a class:

```
class POINT inherit
    TRIGONOMETRY
create
    make_polar, make_cartesian

feature -- Access
    ro, theta: REAL
    x, y: REAL

feature -- Element change
    make_polar (r, t: REAL) is
            -- Set to polar coordinates r, t.
        do
            ro := r; theta := t
            reset_from_polar
        end

    make_cartesian (a, b: REAL) is
            -- Set to cartesian coordinates a, b.
        do
            x := a; y := b
            reset_from_cartesian
        end

    … Other exported features …

feature {NONE} -- Implementation
    consistent_attributes: BOOLEAN is
            -- Do polar and cartesian attributes
            -- represent same point?
        do
            Result := (x = ro * cos (theta)) and
                (y = ro * sin (theta))
        end

    reset_from_polar is
            -- Update cartesian coordinates from polar ones.
        do
            x := ro * cos (theta); y := ro * sin (theta)
        ensure
            consistent_attributes
        end

    reset_from_cartesian is
            -- Update polar coordinates from cartesian ones.
        do
            …
        ensure
            consistent_attributes
        end

invariant
    consistent: consistent_attributes
end
```

This example assumes a library class TRIGONOMETRY offering functions such as cos and sin. The equality in consistent_attributes should be changed to an approximate equality to account for numerical precision issues.

With this design, the author of class *POINT* provides clients with two creation mechanisms: one initializes a point by its polar coordinates, the other by its cartesian coordinates. Examples of Creation_instruction, assuming that *point1* is a Writable entity of type *POINT*, are

```
create point1.make_polar (2, Pi / 4)
create point1.make_cartesian (Sqrt2, Sqrt2)
```

If Pi and Sqrt2 are real constants with the values suggested by their names, these instructions will have the same effect.

Names of the form *make_something* are common practice for creation procedures, although by no means required. When a class has just one creation procedure, or one more fundamental than the others, the convention is to call it just *make* — although if the procedure has no arguments your clients can ignore it altogether, if you use *default_create* as will now be seen.

20.4 OMITTING THE CREATION PROCEDURE

In some common cases you can avoid specifying a creation procedure. This gives the simplest possible form of Creation_instruction, illustrated by the first of our initial examples:

```
create x
```

This form is applicable when the base class *C* of *x*'s type does *not* have a Creators part. This is particularly useful for simple classes which do not need particularly flexible creation mechanisms, but just provide clients with a standard way to create instances without providing any specific information. These instances will all be initialized in the same way. A simple example is

```
indexing
	description: "%[Binary trees with nodes containing
			information of type G%]"
class BINARY_TREE [G]… feature -- Access
	item: G
		-- Node information
	left, right: BINARY_TREE [G]
		-- Left and right children
feature -- Element change
	… Features to set node information and attach children…
end -- class BINARY_TREE
```

Here a creation instruction, for *bt* of type *BINARY_TREE* [*SOME_TYPE*], will simply be

```
create bt
```

and will set all the fields of the resulting object to their default values: void references for *left* and *right*, the default value of the actual generic parameter (whatever it may be) for *item*.

This simple form of the Creation_instruction is appropriate when the object-creating client is happy to rely on a standard initialization. But even in this case you may need more fine-tuning, because the language-defined default initializations might not suit all classes. Consider

```
class EMPLOYEE inherit
    PERSON
feature -- Access
    Unknown_marital_status, Single, Widowed, Divorced:
        INTEGER is unique
    marital_status: INTEGER
feature
    … Other features …
invariant
    meaningful_marital_status:
        marital_status >= Unknown_marital_status and
        marital_status <= Divorced
end -- class EMPLOYEE
```

We require, as expressed by the invariant, that *marital_status* have one of the **unique** values listed. Because this attribute is of type *INTEGER*, the universal default initializations would set it to zero — not compatible with the invariant! Remember the Creation principle: it is creation's responsibility to ensure that every new object satisfies the invariant.

← The "Unique Declaration semantics", page 396, stated that **unique** *values are always positive.*

Creation principle: page 409.

One solution is to use a creation procedure:

```
class EMPLOYEE inherit
    PERSON
create
    make
feature -- Initialization
    make is
            -- Initialize by setting marital status to "Unknown".
        do
            marital_status := Unknown_marital_status
        end

feature -- Access
    … Other features and invariant as before …
end -- class EMPLOYEE
```

Since the class now has a Creators part, the abbreviated form **create** *emp* (for *emp* of type *EMPLOYEE*) is no longer valid: we are back to the previous technique and must write

```
create emp.make
```

This approach works but is a bit tedious for the clients since they must specify a creation procedure for no clear benefit: only one such procedure is available, *make*, and it takes no argument.

In such a case — providing a standard initialization, but not necessarily the universal language-defined one — you can still make the simple creation form **create** *x* valid for your clients. Do not include a Creators part; just redefine the procedure *default_create* which, coming from class *GENERAL*, is a feature of all classes. This redefinition will specify your desired initializations.

This technique relies on a simple convention: any class *C* without a Creators part is treated as if it had one of the form

```
create
    default_create
```

(If *default_create* has been renamed, this should use the new name instead.) In other words, a class which doesn't list any creation procedures is considered to have just one — its version of *default_create*.

Correspondingly, a Creation_instruction of the form **create** *x*, which doesn't specify a creation procedure, is treated as a shorthand for

```
create x.default_create
```

for *x* of a type based on *C* (again with the understanding that, if *default_create* has been renamed, this unfolded form uses the new name).

With this technique we can adapt class *EMPLOYEE* so that its clients can create instances by writing just

```
create emp
```

with no creation procedure. The new form of the class is almost the same as the last one seen, but instead of a specific creation procedure *make* we don't include any Creators part and just redefine *default_create*:

```
class EMPLOYEE inherit
    PERSON
        redefine default_create end

feature -- Initialization

    default_create is
            -- Initialize by setting marital status to “Unknown”.
        do
            marital_status := Unknown_marital_status
        end

feature -- Access
    … Other features and invariant as before …
end -- class EMPLOYEE
```

Because such a class redeclares a feature *default_create* which it inherits in non-deferred form, it must state **redefine** *default_create* in some Inheritance part. Here *EMPLOYEE* inherits from *PERSON*, so we just stick this clause into the corresponding Inheritance part. If the class didn’t have any Inheritance part — meaning that it only has an implicit parent, *ANY* — we would have to use the standard idiom enabling such a class to redefine a feature coming (through *ANY*) from *GENERAL*: include an Inheritance part making *ANY* an explicit rather than implicit parent. This would give:

```
class EMPLOYEE inherit
            -- Here we make ANY an explicit parent:
    ANY
        redefine default_create end
feature -- Initialization
    … Feature clauses and invariant as before …
end -- class EMPLOYEE
```

Let’s review the two schemes studied in the previous section and this one:

1 • To provide clients with specific creation procedures, which may take arguments, include at the beginning of the class a Creators part, of the form **create** *cp1*, *cp2*, … , where the cp_i are procedures of the class. A Creation_instruction in this case must be of the form **create** *x*.*cp* (…) where *cp* is one of the specified cp_i.

2 • To make the simplified form **create** *x* valid, you do not need to include any Creators part: this form is equivalent to the previous case using for *cp* the procedure *default_create*; and an absent Creators part is equivalent to one that lists only that procedure.

At first these two cases may seem incompatible, but if you examine them more closely you will realize they are not. The rule is simply that the simplified form **create** *x* is valid if and only if *default_create*, in its local version, is one of the creation procedures of the class. You can achieve this property by not listing any creation procedures at all: this is equivalent to listing *default_create* only. But you can also have a Creators part, provided it lists *default_create*, possibly among other procedures. This observation yields a third case, combining the previous two:

3 • To make both forms of creation instruction valid — the form with an explicit procedure, **create** $x.cp_i$ (…) for some cp_i, and the procedure-less form, **create** *x* — simply include a Creators part that lists both the desired cp_i and the class's version of *default_create*.

Here is an example of this last scheme, a variation on an earlier class text:

← *See the original version on page 412.*

```
class POINT inherit
        TRIGONOMETRY
create
        make_polar, make_cartesian, default_create
feature
        … Features as before …
invariant
        consistent: consistent_attributes
end
```

Then all of the following four creation instructions are valid:

```
[1]
        create your_point.make_polar (2, Pi/4)
[2]
        create your_point.make_cartesian (Sqrt2, Sqrt2)
[3]
        create your_point.default_create
[4]
        create your_point
```

Forms 3 and 4 are exactly equivalent, so there is usually little reason to use 3 except if you insist on including the creation procedure for clarity.

Note that including *default_create* among the creation procedures, hence permitting 4, makes sense only because the default initializations ensure the invariant *consistent_attributes*, which states that cartesian and polar coordinates agree — true if they are all zero, the default. When thinking about creation, always keep in mind the Creation principle.

← *Creation principle: page 409.*

As a variation on this example, assume that you write a class *C* that inherits from a parent *B* a procedure *set* without arguments, and want *C* to offer its clients the procedure-less form **create** *x* so that it will call *set* for initialization. A simple technique is:

```
class C inherit
    B
        rename
            default_create as discarded
        end
    ANY
        rename
            default_create as set
        undefine
            set
        select
            set
        end
feature
    …
end -- class C
```

This uses a **join** to merge two inherited features, undefining *default_create* along one of the branches so that its joined feature *set* can override its previous implementation. Corresponding creation instructions may be written **create** *x*.

← See "THE JOIN MECHANISM", 10.19, page 204.

We can now summarize the basic rule for validity of a creation instruction: the *instruction's creation procedure* must be one of the *class's creation procedures*, with the understanding that:

1 • Every creation instruction uses a creation procedure — either explicit, as in **create** *x*.*cp* (…), or implicit, as in **create** *x*, where the instruction's creation procedure is *default_create*.

2 • Every class lists a set of creation procedures — either explicit, if the class has a Creators part, or implicitly taken to be *default_create* in the absence of a Creators part.

This also suggests, as a special case, what you should do if for some reason you do **not** want clients of a class to create any direct instances of it. Simply include a Creators part, but make it empty:

WARNING: not the recommended style; see next.

```
class NOT_INSTANTIABLE create
    -- Nothing at all listed here!
feature
    …
end -- class NOT_INSTANTIABLE
```

This falls under the "explicit" case of observation 1 above, so that under observation 2 a creation instruction could only be valid if it were of the form **create** *x*.*cp* (...) where *cp* is a creation procedure of the class; but there is no such *cp* since the Creators part, although present, is empty.

The style guideline in such a case is actually to write

```
class NOT_INSTANTIABLE create {NONE}

feature
    ...
end -- class NOT_INSTANTIABLE
```

which has exactly the same effect but emphasizes the creation ban by listing *NONE* as the single creation (rather, non-creation) client, based on conventions, seen below, for restricting creation availability.

→ "RESTRICTING CREATION AVAILABILITY", 20.7, page 425.

Another way to make a class non-instantiable is to declare it as deferred. But you might want to prohibit instantiation of a class even if it is effective. Then you can use the technique just seen.

20.5 CREATORS AND INHERITANCE

(This section is a discussion of the *absence* of dependency between two language concepts, so it introduces no new mechanism; it is a "comment" and "methodology" section meant to dispel a possible confusion, which might in particular follow from experience with other languages.)

You may have been wondering what effect the inheritance structure has on the creation procedures of a class. The short answer is: *no effect*. Each class is free to choose the procedures it wants to offer to its clients for creation, regardless of its parents' choices. The creation mechanism does of course take full advantage of inheritance: creation procedures may be obtained from parents and adapted through the usual inheritance mechanisms of redefinition, renaming, effecting and so on. And in some cases a class's choice of creation procedures is directly connected to its parents' choices:

- A class may list as creation procedures (in its Creators part) some or even all of a parent's own creation procedures.
- A redefined creation procedure may need, as part of its execution, to call the parent's version, usually through the Precursor mechanism.

But all this is optional, not required, and neither theoretical analysis nor analysis of practical examples suggests an obligatory connection. Counter-examples indeed abound. Just think of a class *POLYGON*, where a typical creation procedure will take a list of vertices; for its heir *RECTANGLE* this is most likely inappropriate, as we might use a center, an orientation and two side lengths; then for a grandchild *SQUARE* we will again need something different since we can dispense with one of these lengths.

So the set of creation procedures of a class is entirely determined by its Creators clause (or lack thereof, as we have seen), without interference from the parents' own clauses. This yields a simple semantics and avoids confusion. Based on the needs of each class, you decide what creation privileges you award to *your* clients; you may reuse the parents' creation procedures, unchanged or extended, but only if you find them useful for your own needs.

Although the business of this book is to describe Eiffel, not to criticize any other language design, we have to make an exception here — not so much a criticism as an expression of bewilderment — because many people have been exposed to the (to me inexplicable) policies of C++ and Java, where "constructors" follow complex rules directing the creation of an object to apply, in turn, the constructors of all proper ancestors — a bizarre idea, perhaps stemming from the old view that ontogenesis repeats phylogenesis: your baby starts out as a bacteria, then successively tacks on properties of amoebas, insects, fish, frogs, mice, pigs, lemurs, lawyers and humans. This is particularly complex in C++ because of multiple inheritance.

Not long ago I sat through a three-hour tutorial with the attractive title "Uses and misuses of inheritance", more than half of which turned out to be a discussion of how best to fight the constructor inheritance properties of C++. No wonder that, with such an approach, people claim that inheritance, multiple inheritance especially, is a difficult and possibly messy topic.

All this is self-inflicted pain, particularly puzzling in the C/C++/Java culture of "leave me in control of my program": why direct the compiler to second-guess the programmer and try to reconstruct a sequence of constructor calls, when the guess is often wrong, and we could just as well let the programmer specify when and how, if at all, he wants the initialization mechanism of a class to rely on those of its ancestors?

Eiffel's policy on relating *creation status* to inheritance is similar to its policy on relating *export status* to inheritance. There too every class is free to make its own decisions for inherited features, regardless of its parents' choices. The only difference is the default: inherited features retain their original export status unless the heir explicitly overrides it (through a New_exports clause); in contrast, a creation procedure loses its creation status unless the heir explicitly reaffirms it (by listing the procedure in its own Creators part). This difference follows from an analysis of what designers most commonly need, in each case, in the practice of building systems.

← "ADAPTING THE EXPORT STATUS OF INHERITED FEATURES", 7.11, page 130.

20.6 USING AN EXPLICIT TYPE

In the variants seen so far, the type of the object created by a creation instruction **create** *x* … , with or without an explicit creation procedure, is the type *T* declared for *x*, the instruction's target. You may want to use another type *V* instead; this will be permitted if *V* conforms to *T*. The form of the instruction in this case is one of

```
create {V} x.cp (..)
create {V} x
```

with the first one valid only if *cp* is a creation procedure of *V*, and the second only if *default_create* is a creation procedure of *V* (in particular if *V*'s base class has no Creators part).

Specifying the creation type

Assume class *SEGMENT* is a descendant of *FIGURE*, and has a creation procedure *make*, with two formal arguments of type *POINT* representing the end points of a segment. The following will be valid:

```
[1]
    fig: FIGURE
    point1, point2: POINT
    …
    create {SEGMENT} fig.make (point1, point2)
```

and will have exactly the same effect on *fig* as

```
[2]
    fig: FIGURE; seg: SEGMENT
    point1, point2: POINT
    …
    create seg.make (point, point2)
    fig := seg
```

where the last instruction is a polymorphic assignment, permitted by the Assignment rule since *seg* conforms to *fig*.

→ *The Assignment rule, stating that the type of an assignment's source must conform to that of its target, is on page 466.*

The explicitly typed form 1 brings nothing fundamentally new; it is just an abbreviation for the implicitly typed form 2, avoiding the need to introduce intermediate entities such as *seg*.

As a consequence of this new form, we can define the **creation type** of a creation instruction — the type of the object that it will create: in the previous form **create** *x* … , the creation type is the type declared for the target, *x*; in the explicit form **create** {*V*} *x* … , the creation type is *V*.

→ *The formal definition will appear on page 435.*

Choosing between types

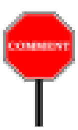
To become really useful the example should include more than one case: after all, if all you ever want to obtain is an instance of *SEGMENT*, then you do not need *fig*; *seg* suffices. Things become more interesting with a scheme of the following kind, using a local entity *fig* of type *FIGURE*:

```
[3]
    inspect
        icon_selected_by_user
    when Segment_icon then
        create {SEGMENT} fig.make (point1, point2)
    when Triangle_icon then
        create {TRIANGLE} fig.make (point1, point2, point3)
    when Circle_icon then
        create {CIRCLE} fig.make (point1, radius)
    when …
        …
    end
```

Here *SEGMENT*, *TRIANGLE*, *CIRCLE*, … are descendants of *FIGURE*, all with specific creation procedures, and *Segment_icon*, *Triangle_icon*, *Circle_icon*, … are integer constants (perhaps Unique) with different values. Depending on the icon selected by an interactive user, the above instruction creates an object of the appropriate type, and attaches *fig* to it.

Were the explicitly typed form of the creation instruction not available, you could still use the equivalence illustrated by 2, rather unpleasant here because you need to declare a temporary entity (*seg*, *tri*, *circ*, …) for each of the possible icon types.

Creation and deferred classes



Scheme 3 helps understand the role of **deferred classes and types** vis-à-vis creation. A class must be declared as **deferred** if it has at least one deferred feature (introduced in the class itself, or inherited from a parent, and not effected — made effective — in the class). A deferred type is one based on a deferred class. In our example we may assume *FIGURE* to be deferred, but the concrete descendants used in the creation instructions — *SEGMENT* and so one — to be effective. The rule is that:

← Although a class may be declared as **deferred** *even without deferred features, the common case is for a deferred class to have one or more deferred features.* *See 10.11, page 187.*

- We *never* permit a creation instruction to use a deferred type as creation type. As noted in the last chapter, creating direct instances of a deferred type would be asking for trouble, since clients could then call unimplemented operations on these instances. The creation rules of this chapter exclude this possibility; with *fig* of type *FIGURE*, we are not permitted to write **create** *fig* … , with or without a creation procedure.

"Direct instance" is in fact not even defined for deferred types. See *"MORE ON TYPE SEMANTICS", 19.4, page 401*.

- We may, however, use *fig* as target of a creation instruction such as **create** {*SEGMENT*} *fig*.*make* (*point1*, *point2*) or any of the others above, even though the type of *fig* is deferred: that's fine as long as the **creation type** of the instruction is explicit and effective, like *SEGMENT* here. The instruction will create a direct instance of that type, so everything is in order. Attaching this object to an entity *fig* of a deferred type is also in order: it's simply an application of polymorphism.

In summary: we cannot create **objects** of deferred types, but we can have **entities** of such types, which will become attached to instances of conforming effective types.

Single choice and factory objects

Beyond its applicability to polymorphic entities of deferred types, what makes scheme **3** especially interesting is its connection with **dynamic binding**: after executing the above Multi_branch instruction, you normally should never have to discriminate again on the type of *fig*; instead, to apply an operation with different variants for the figures involved, you should use a call of the form

```
fig.display
```

where the operation, here *display*, is redefined in various ways in descendants of *FIGURE*. This will select the appropriate version depending on the exact type of the object to which *fig* is attached, as a result of the variable-type creation achieved by 3.

This example illustrates an important concept of Eiffel software development: the **Single Choice principle**. The principle states that in a software system that handles a number of variants of the same notion (such as the figure types in a graphics system) any exhaustive knowledge of the set of possible variants should be confined to just **one component** of the system. This is essential to prevent future additions and modifications from requiring extensive system restructuring.

See also 16.6, page 366, on explicit discrimination. For further discussion of these issues see "Object-Oriented Software Construction", in particular the Open-Closed Principle. .

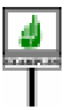
Often, the component that performs the “Single Choice” will be the one that initially creates instances of the appropriate objects; 3 illustrates one of the possible schemes.

There is a simpler scheme, avoiding any explicit control structure: the *clonable array technique*, implementing what the Design Pattern literature calls the **Factory Pattern**, although it was described in Eiffel literature and widely used in Eiffel programs many years before that term appeared in print.

Here is how it would work in this example. You assign a unique code to every variant

```
Low_id, Segment_id, Triangle_id, Circle_id, … , High_id:
            INTEGER is unique
                  -- Figure codes.
                  -- (Low_id and High_id are unused end markers.)
```

and create a data structure, most conveniently an array, containing one direct instance of each variant:



```
[4]
      figure_factory: ARRAY [FIGURE] is
            local
                  fig: FIGURE
            once
                  Result.make (Low_id, High_id)

                        -- Create and enter a SEGMENT instance:
                  create {SEGMENT} fig.make (…)
                  Result.put (fig, Segment_id)

                        -- Create and enter a TRIANGLE instance:
                  create {TRIANGLE} fig.make (…)
                  Result.put (fig, Triangle_id)

                  … Do the same for each variant …
            end
```

WARNING: there is a much more concise way to express this, using creation expressions and avoiding altogether the need to declare a local entity fig. See 1, page 442, which is the model you should use for this pattern.

Instead of making *figure_factory* a once function you can declare it as an attribute, and then initialize it accordingly (with the instructions of the above routine body, substituting *figure_factory* for *Result*) in an initialization module. But initialization modules that take care of initializations for many different aspects of a system are not good for modular, extensible software construction. Using a once function is usually a better approach since it has the same effect but lets the initialization happen automatically the first time any part of the system needs to access *figure_factory*.

Then, whenever you actually need to select an alternative, you can avoid the explicit discrimination of **3**: replace the *entire* Multi_branch instruction by

figure_factory @ code denotes the item of index *code*, also written *figure_factory.item (code)*; see 33.4, page 736.

```
[5]
        fig := clone (figure_factory @ code)
```

where *code* is the desired figure code (one of *Segment_id*, *Triangle_id* etc.). The function *clone* appearing on the right-hand side produces a new object copied from its argument; so each time you use **5** you get a new object which, depending on the value of the index *code*, will be a *SEGMENT*, or a *TRIANGLE* and so on.

→ "CLONING AN OBJECT", 21.3, page 452.

20.7 RESTRICTING CREATION AVAILABILITY

The Creators parts in the preceding examples had at most one Creation_clause, and any client could create direct instances through any of the creation procedures listed there. It is also possible to define more restrictive client creation privileges. Let us take a look at this simple facility which, although not needed in elementary uses, helps build well-engineered systems that thoroughly apply the principle of information hiding.

← See 7.7, page 126, on information hiding.

You may indeed write a Creators part with one or more Creation_clause listing procedures available for creation by specific clients, as in

```
class C … create
        make
create {A, B}
        jump_start, bootstrap
feature
        …
end -- class C
```

The first Creation_clause has no restriction, so that any client can create a direct instance of *C* through an instruction **create** *x*.*make* (…) for *x* of type *C*. Because of the restriction in the second clause, however, only the descendants of *A* and *B* may use the given procedures for creation, in instructions **create** *x*.*jump_start* (…) or **create** *x*.*bootstrap* (…).

Remember that descendants of a class include the class itself.

This possibility of including more than one Creation_clause, each specifying that certain procedures of the class are creation procedures and giving a creation availability status, is, as you will certainly have noted, patterned after the convention for making the features of a class available to clients with a specified export status for calls. In the same way that a Feature_clause may begin with one of

← "RESTRICTING EXPORTS", 7.8, page 128.

```
[1]
    feature
            … Declaration of features callable by all clients …
    feature {NONE}
[2]
            … Declaration of features callable by no clients …
[3]
    feature {X, Y}
            … Declaration of features callable by descendants
              of X and Y …
```

a Creation_clause may begin with one of

```
[4]
    create
            … List of procedures available for creation to all clients …
[5]
    create {NONE}
            … List of procedures available for creation to no clients …
[6]
    create {X, Y}
            … List of procedures available for creation
              to descendants of X and Y …
```

Note, however, that such flexibility is not as essential for creation as it is for feature call. As part of the fundamental O-O principles of abstraction and information hiding, it is common to have several feature clauses specifying different levels of call availability: to all clients, to some clients, to no clients. This is less frequently useful for creation, and in practice many classes have just one Creation_clause, or none.

The language supports the full generality of the mechanism anyway, partly for consistency with the other mechanism, and partly because the extra control over creation availability is occasionally useful.

Make sure not to confuse the two forms of specifying availability. When you list a set of creation procedures, as in **4**, **5** and **6** for a class *C*, you are only controlling the validity of a Creation_instruction involving a creation call, such as

```
[7]
    create x.cp (…)
```

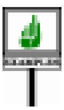
for *x* of type *C*: valid everywhere in case **4**, invalid everywhere with **5**, and valid only in descendants of *X* and *Y* with **6**. This is completely independent of the availability status for plain (non-creation) calls such as

```
[8]
    x.cp (…)
```

valid everywhere in case **1**, invalid everywhere with **2**, and valid only in descendants of *X* and *Y* with **3**. For the same *cp*, the two properties are separate. They reflect different semantics:

- The creation call **create** *x*.*cp* (…) creates an object and initializes it using *cp*.
- The plain call *x*.*cp* (…) uses *cp* to reinitialize an existing object – a right which, as the designer of a class, you may decide to grant or not to grant to clients, regardless of the right you have granted regarding the use of *cp* for creation-time initialization.

You may indeed be justified in deciding on different privileges in each case. Consider a class manipulating bank accounts:



```
class
    ACCOUNT
create
    make
feature {NONE} -- Initialization
    make (initial: AMOUNT) is
        -- Set balance to initial.
        is do … end
feature -- Element change
    withdraw (a: AMOUNT) is
            -- Record removal of a units of currency.
        do … end
    deposit (a: AMOUNT) is
            -- Record addition of a units of currency.
        do … end
    … Other features, invariant …
end-- class ACCOUNT
```

The use of **feature** {*NONE*} for the declaration of the class's creation procedure is a common Eiffel idiom, but surprising at first here: why hide this fundamental operation on the class? The reason is that we are hiding it for call, not for creation. The Creation_instruction

```
create your_account.make (some_amount)
```

is indeed valid since *make* appears in an unrestricted Creators clause (lines 3 and 4, highlighted in the class above). What is **not** valid is a plain call

```
your_account.make (some_amount)
```

WARNING: not valid with class text as given.

which would reinitialize the account to *some_amount*. The author of class *ACCOUNT* has decided that the only way to affect the balance of an account is to deposit or withdraw money (adding a value, positive or not, to the balance, rather than setting it to a specified value). Such policies are often legitimate and explain why **feature** {*NONE*} is a common style for declaring a creation procedure, even one that is unrestrictedly available for creation.

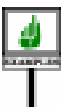
20.8 THE CASE OF EXPANDED TYPES

The preceding examples assumed that the type of the target entity was a reference (non-expanded) type. What if it is expanded?

In this case there is no need to create an object, since the value of the target is already an object, not a reference to an object that a Creation_instruction must allocate dynamically.

Rather than disallowing Creation_instruction for expanded targets, it is convenient to define a simple semantics for the instruction in this case, limited to the steps of the above process that still make sense: the instruction will execute the default initializations on the object attached to the target, then call the appropriate version of *default_create*. This convention also has the advantage that if you change your mind about the expanded status of a class you can change it without to worry about its Creation_clause becoming invalid.

As a consequence of this rule, if we have a class whose instances contain sub-objects, as in



```
class COMPOSITE feature
    a: SOME_REFERENCE_TYPE
    b: SOME_EXPANDED_TYPE
    …
end -- class COMPOSITE
```

then the default initialization rule for the *b* field of a *COMPOSITE* instance will be to apply a Creation_instruction, recursively, to the corresponding sub-object. This creation instruction will use as creation procedure the version of *default_create* in the corresponding base class.

This semantic rule justifies a basic constraint on expanded types (given in the chapter on types as clause 2 of the Expanded Type rule): the base class of an expanded type **must** have its version of *default_create* as one of its creation procedures (either explicitly in its Creators part, or implicitly by not having a Creators part). This does not prevent the class from having other creation procedures if desired; but for automatic initialization of sub-objects such as *b* the procedure to be applied is *default_create*, as any other choice would require further information from the client (choice of creation procedure and actual arguments).

← *Page 244*,

20.9 CREATING INSTANCES OF FORMAL GENERICS

More delicate than the expanded types is the case in which we would like to create an instance of one of the Formal_generic parameter types of a class, as in **create** *x*.. where *x* is of type *G* in a class *C* [*G*].

The problem is that *G*, in the class text, denotes not a known type but a placeholder for many possible types or, in the case of unconstrained genericity, *any* valid type. So we have no way to know what creation procedures will be available on the corresponding instances.

This seems at first to preclude any hope of allowing creation instructions in this case. Fortunately, constrained genericity allows an elegant solution.

As you know, constrained genericity is the mechanism that allows us to declare a class as

← “CONSTRAINED GENERICITY”, 12.4, page 258,

```
class C [G –> CONST] …
```

where *CONST* is a type, known as the constraining type for the formal generic parameter *G*. Then you may only write a generic derivation *C* [*T*], using a type *T* as actual generic parameter, if *T* conforms to *G*. The benefit is that, within class *C*, you know that any entity *x* of type *G* represents objects of type *T* or conforming, so you may apply to *x* any of the features of *T* — rather than being limited, as in the unconstrained case *C* [*G*], to the features of class *ANY*, applicable to all types.

A small syntactic extension enables us to take advantage of constrained genericity to allow creation of objects of generic type. Declare the class as

```
class D [G –> CONST create cp1, cp2, … end] …
```

to state that *G* represents any type that both:

- (As always with constrained genericity) conforms to *CONST*.
- Admits as creation procedures its versions of *cp1*, *cp2*, … , which must be procedures of *CONST*.

These obligations are enforced: a generic derivation *D* [*T*] will only be valid if (as always) *T* conforms to *CONST* and, in addition, the given procedures *cp1*, *cp2*, … are creation procedures of *T*. More precisely, their **versions** in *T* — which may differ from the originals versions in *CONST* as a result of renaming, redefinition and effecting — must be listed among the creation procedures of *T*.

With *D* declared as shown, it becomes possible, for *x* declared of type *G* in the text of class *D* itself, to use a creation instruction

```
create x.cpi (args)
```

where cp_i is one of the procedures of *D* listed in the **create** … **end** part for *CONST* as shown above, and *args* is a valid argument list for that procedure. The instruction will always make sense dynamically since, thanks to the preceding rule, the type *T* of *x* — in any valid generic derivation *D* [*T*] — will always be a descendant of *CONST*, so that:

- cp_i will be one of its procedures, taking the appropriate arguments.
- *T* will have listed cp_i as one of its creation procedures (hence, among other properties, we may expect that cp_i ensures the invariant of *T*).

As a special case, you can permit the procedure-less form **create** *x* by including *default_create* (rather, its name in *CONST*) among the cp_i.

What's particularly useful in this mechanism is that at the level of *D* we only require the listed cp_i to be **procedures** of the constraining type *CONST* — so that we can ascertain, from *D*'s text only, the validity of *args* as arguments in the creation call **create** *x*.cp_i (*args*): we do not require the cp_i to be **creation procedures** of *CONST*. This last requirement will only come up where it matters: in types *T*, descendants of *CONST* used in actual generic derivations *D* [*T*]. In such a *T*, the local version of cp_i must indeed be one of *T*'s creation procedures.

This means in particular that the above scheme will work even if *CONST* is deferred, as in

```
class
	D [G –> CONST create cp end]
feature
	some_routine is
		local
			x: G
		do
			create x.cp (3)
		end
end -- class D

deferred class CONST feature
	cp (n: INTEGER) is
		… Could be effective or deferred …
		end

	… Other features, possibly including deferred ones …
end -- class CONST
```

We don't care that the boxed creation instruction works on a target *x* whose type *G* is based on a deferred class *CONST*, and that the creation procedure *cp* might itself be deferred in *CONST*: any type *T* used for *G* in practice must make its version of *cp* a creation procedure. This implies among other things that *T* is an effective class and *cp* an effective procedure, so everything will work properly.

Note that this creation mechanism for formal generics assumes *constrained* genericity. In a class *C* [*G*], where *G* is an *unconstrained* generic parameter, no creation instruction **create** *x* … is valid for *x* of type *G*. This includes the procedure-less form **create** *x*: making it valid would mean assuming that *default_create* will be a creation procedures in all possible types — certainly not true. You can, however, write the class as

class *C* [*G* –> *ANY* **create** *default_create* **end**]

thereby unfolding unconstrained genericity into its constrained equivalent. Then the generic derivation *C* [*T*] will be valid for a type *T* if and only if *T*'s base class doesn't list any creation procedures, or lists *default_create* among its creation procedures. With this form of *C*'s declaration, **create** *x* is valid in the text of class *C*.

More generally, remember that the procedure-less form **create** *x* is only valid, for *x* of a formal generic type, if you have explicitly listed *default_create* (under its local name) in a **create** subclause after the constraint. There is no equivalent here to the implicit rule of the Creators part, where requesting no creation procedures means requesting *default_create* only. For generic parameters, you don't get creation privileges unless you specify them expressly.

20.10 CREATION SYNTAX AND VALIDITY

Here now are the precise rules applying to Creators parts and Creation instructions. This section only formalizes previously introduced concepts, so on first reading you may skip this section and the next two (which formalize the semantics).

If skipping, go to "CREATION EXPRESSIONS AND ANONYMOUS OBJECTS", 20.14, page 441.

First, the syntax of a Creators part, an optional component of the Class text, appearing towards the beginning of a class, after Inheritance and before Features:

The structure of a Class *text, with all its parts, is on page 61.*

Creators	≜	**create** {Creation_clause **create** …}*
Creation_clause	≜	[Clients] [Header_comment] Creation_procedure_list
Creation_procedure_list	≜	{Creation_procedure "**,**"…}$^+$
Creation_procedure	≜	Feature_name [Conversion_types]

The optional Header_comment *emphasizes the similarity with the syntax of a* Feature_clause, *given page 77.*

To talk about the validity and semantics of creation clauses and creation instructions, it is useful to take care once and for all of the special case of *default_create* as creation procedure through the following definition:

Unfolded Creators part of a class

Every effective class *C* has an **unfolded** Creators **part**, defined as:

1 • If *C* has a Creators part, that part itself.

2 • Otherwise, a Creators part built as follows, *dc_name* being the final name in *C* of procedure *default_create* from *GENERAL*:

```
create
    dc_name
```

Case 2 reflects the rule, given informally in previous sections, that an absent Creators part stands for **create** *dc_name* — normally **create** *default_create*, but *dc_name* may be another name if the class or one of its proper ancestors has renamed *default_create*.

With this we can define the constraint on Creators part of a class:

Creation Clause rule *CGCC*

A Creation_clause in the unfolded Creators part of a class *C* is valid if and only if it satisfies the following four conditions, the last three for every Feature_identifier *cp_name* in the clause's Feature_list:

1 • *C* is effective.

2 • *cp_name* appears only once in the Feature_list.

3 • *cp_name* is the final name of some procedure *cp* of *C*.

4 • *cp* is not a once routine.

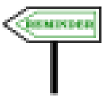
Note that in practice there is a further condition: if *C* is expanded, *default_create* must be one of the listed creation procedures to permit proper sub-object initialization. There is no such condition, however, in the present rule: we don't invalidate the *declaration* of an expanded class just because it fails to make *default_create* a creation procedure; but the Expanded Type rule will invalidate any *use*of this class to define composite objects.

← *Expanded Type rule: page 244. See "THE CASE OF EXPANDED TYPES", 20.8, page 428.*

As a result of conditions 1 and 4, a creation procedure may only be of the **do** form (the most common case) or External.

The prohibition of **once** creation procedures in clause 4 is a consequence of the Creation principle: with a once procedure, the first object created would satisfy the invariant (assuming the creation procedure is correct), but subsequent creation instructions would not execute the call, and hence would limit themselves to the default initializations, which might not ensure the invariant.

As a corollary of clause 4, a class that has no explicit Creators part may not redefine *default_create* into a once routine, or inherit *default_create* as a once routine from one of its deferred parents. (Effective parents would themselves violate the clause and hence be invalid.)

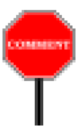


To complement this study of the syntax and semantics of Creators parts, it is useful to remind ourselves of their counterpart for generic parameters: the Constraint_creators subclause of the syntax for generic constraints, a simplified form of the Creators part. Here is the relevant syntax:

Formal_generics	≜	"["Formal_generic_list"]"
Formal_generic_list	≜	[Formal_generic","…]
Formal_generic	≜	Formal_generic_name [Constraint]
Formal_generic_name	≜	Identifier
Constraint	≜	"–>" Class_type [Constraint_creators]
Constraint_creators	≜	**create** Feature_list **end**

← *This was first seen in the chapter on types; syntax on page 257, validity in "CONSTRAINED GENERICITY", 12.4, page 258.*

The applicable validity rule there was that the elements of the Feature_list must be the names of distinct procedures of the constraining type — corresponding to clauses 1 and 2 of the Creation Clause rule above. There was no need for an equivalent to the other clauses since they are taken care of by the Creation Clause rule itself when we provide an actual generic parameter conforming to the constraining type.



A language design note: it would have been possible to use Creators for Constraint_creators, permitting a more flexible form of creation availability specification for a generic parameter — with more than one Creation_clause, each listing specific clients and procedures. This would in fact make the language definition simpler by avoiding the construct Constraint_creators. The extra capabilities, however, seems useless, and could yield unduly complicated Formal_generics parts, so the language sticks to a primitive form of Constraint_creators for generic parameters.

The Creation Clause rule allows us to define the set of creation procedures of a class:

Creation procedures of a class

The **creation procedures** of a class are all the procedures appearing in any Creation_clause of its unfolded Creators part.

If there is an explicit Creators part, the creation procedures are the procedures listed there. Otherwise there is only one creation procedure: the class's version of *default_create*.

Only in the first case (explicit Creators part) can the set of creation procedures be empty: this is achieved, as we have seen, by including a Creators part, but an empty one, listing no name at all.

← *See the example class NOT_INSTANTIABLE on page 418.*

We need a small refinement of this definition to extend it to the case of types, to support the mechanism for creation on generic parameters:

← *See "CREATING INSTANCES OF FORMAL GENERICS", 20.9, page 429.*

Creation procedures of a type

The **creation procedures** of a type *T* are:

1 • If *T* is a Formal_generic_name, the procedures, if any, listed after the associated generic constraint if any.

2 • Otherwise, the creation procedures of *T*'s base class.

The definition of case 2 is not good enough for case 1, because in the scheme **class** *D* [*G* –> *CONST* **create** *cp1*, *cp2*, … **end**] … studied earlier it would give us, as creation procedures of *G*, the creation procedures of *CONST*, and what we want is something else: the set of procedures *cp1*, *cp2*, … specifically listed after *CONST*. These are indeed procedures of *CONST*, but as we have seen they are not necessarily *creation* procedures of *CONST*, especially since *CONST* can be deferred. What matters is that they must be creation procedures in any descendant of *CONST* used as actual generic parameter for *G*.

Other useful definitions:

Available for creation; general creation procedure

A creation procedure of a class *C*, listed in a Creation_clause *cc* of *C*'s unfolded Creators part, is **available for creation** to the descendants of the classes given in the Clients restriction of the *cc*, if present, and otherwise to all classes except *GENERAL*.

If there is no Clients restriction, the procedure is said to be a **general creation procedure**.

As with a Feature_clause, *the absence of a* Clients *restriction is equivalent to a restriction of the form* {*ANY*}.

Remember, once again, that the descendants of a class include the class itself. The exclusion of *GENERAL* is a way to state that a Creation_clause with no Clients part, as in **create** *cp1*, *cp2*, …, is a shortcut for one with a Clients part listing only *ANY*, as in **create** {*ANY*} *cp1*, *cp2*, … Class *GENERAL*, *ANY*'s parent, is the only class that is not a descendant of *ANY*.

Now for the Creation_instruction itself, starting with its syntax:

Creation_instruction	≜	**create** [Explicit_creation_type] Creation_call
Explicit_creation_type	≜	"**{**" Type "**}**"
Creation_call	≜	Writable [Explicit_creation_call]
Explicit_creation_call	≜	"**.**" Unqualified_call

Every creation instruction has a *creation type*, explicit or implicit:

Creation type

The creation type of a creation instruction, denoting the type of the object to be created, is:

- The Explicit_creation_type appearing (between braces) in the instruction, if present.
- Otherwise, the type of the instruction's target.

so that in

```
account1: ACCOUNT; point1, point2: POINT; figure1: FIGURE
…
create account1
create point1.make_polar (1, Pi/4)
create {SAVINGS_ACCOUNT} account1
create {SEGMENT} figure1.make (point1, point2)
```

the creation types for the four instructions are *ACCOUNT*, *POINT*, *SAVINGS_ACCOUNT* and *SEGMENT*.

The creation type of a Creation_instruction is the type of the objects that it may create. It will always satisfy the following property:

Creation Type theorem

The creation type of a creation instruction is always effective.

This theorem is corollary 1 of the Creation Instruction rule, seen next. That rule will need one more auxiliary definition:

→ *The corollary is on page 438.*

Unfolded form of a creation instruction

Consider a Creation_instruction *ci* of creation type *CT*. The unfolded form of *ci* is a creation instruction defined as:

1 • If *ci* has an Explicit_creation_call, then *ci* itself.

2 • Otherwise, a Creation_instruction obtained from *ci* by making the Creation_call explicit, using as feature name the final name in *CT* of *GENERAL*'s *default_create* procedure.

This definition parallels the earlier one of "unfolded Creators part of a class" and expresses the property, stated informally before, that we understand the procedure-less form of creation **create** *x* as a shortcut for **create** *x*.*default_create* (with the new name for *default_create* if different).

A final notion that the Creation Instruction rule will need is a property defined only in a subsequent chapter, but already presented informally in the discussion of calls, and in fact rather obvious: the concept of a call being **argument-valid**. This property is part of the more complete definition of call validity; it states that in a call *x*.*f* (*a*, *b*, *c*) where *x* is of type *T* and *f* is a feature of *T* with formal arguments *u1*: *T1*; *u2*: *T2*; *u3*: *T3*, the number of actual arguments *a*, *b*, *c* must be the same as the number of these formal arguments, here three, and each actual's type must conform to the corresponding formal's type — here the type of *a* to *T1*, of *b* to *T2*, and of *c* to *T3*. We of course expect this fundamental property to hold for all calls, and must enforce it for a creation instruction **create** *x*.*f* (*a*, *b*, *c*) involving a Creation_call. This is clause C of the following rule.

→ *For the full definition see the "Argument rule", page 538.*

We indeed by now have enough preparation to express the validity rule for creation instructions:

Creation Instruction rule *CGCI*

A Creation_instruction of creation type *CT*, appearing in a class *C*, is valid if and only if it satisfies the following three conditions:

A • *CT* is a descendant of the target's type.

B • The feature of the Creation_call of the instruction's unfolded form is available for creation to *C*.

C • That Creation_call is argument-valid.

→ *Another version of this rule appears below, page 438, with clauses labeled by numbers rather than letters.*

I can see that puzzled look on your face: surely, with all the possibilities seen in this chapter, the complete validity constraint for creation instructions must be longer? But in fact this is all there is to say, thanks to the auxiliary definitions of "*creation type*", "*unfolded form*" of both a Creation_instruction and a Creators part, "*available for creation*" and so on. The rule captures in particular the following cases:

- *CT* may not be deferred: a deferred class may not have any creation procedures as per clause 1 of the Creation Clause rule, so it would be impossible for the feature of the call to be "available for creation" to C. This prohibition is important since, if creation was permitted on deferred classes, it would be possible to call deferred routines on the resulting objects; but such routines cannot be executed. So the various rules of the language are designed to make sure that deferred class can have no direct instances.

← *Creation Clause rule*: *page 432*.

- The procedure-less form **create** *x* is valid only if *CT*'s version of *default_create* is available for creation to *C*; this is because in this case the unfolded form of the instruction is **create** *x*.*dc_name*, where *dc_name* is *CT*'s name for *default_create*. On *CT*'s side the condition implies that there is either no Creators part (so that *CT*'s own unfolded form lists *dc_name* as creation procedure), or that it has one making it available for creation to *C* (through a Creation_clause with either no Clients specification or one that lists an ancestor of *C*).
- If *CT* is a Formal_generic_name, its creation procedures are those listed in the **create** subclause after the constraint. So **create** *x* is valid if and only if the local version of *default_create* is one of them, and **create** *x*.*cp* (…) only if *cp* is one of them.

These and other properties follow from the Creation Instruction rule as given. The very compactness and abstraction of the rule, however, may make it less suitable for one of the applications of validity constraints: enabling compilers to produce precise diagnostics for validity errors. For that reason, the Creation Instruction rule has a second variant, presented next. Unlike the first variant and other validity rules of this book, it is stated in "*only if*" style rather than the usual "*if and only if*", since it limits itself to a set of necessary validity conditions. (All together, these conditions do come close to the full set of sufficient conditions listed in the first variant, but we don't really care, since that first variant gives us the "*if and only if*" property that we need.)

Because the second variant is really just a different presentation of the same properties, the two variants have the same name, Creation Instruction rule, and the same code, *CGCI*. To avoid confusion, the second variant is labeled "corollaries", and its clauses identified by numbers whereas the first variant used letters. This leaves compiler writers free to refer, in error messages, to the clauses of either variant.

For the language definition, **the official rule is the first variant**; the second one is a complement meant to help understanding the rule and provide more precise error reporting.

Creation Instruction rule (corollaries) *CGCR*

A Creation_instruction *ci* of creation type *CT*, appearing in a class *C*, is valid only if it satisfies the following conditions, assuming *CT* is not a Formal_generic_name and calling *BCT* the base class of *CT* and *dc* the version of *GENERAL*'s *default_create* in *BCT*:

1 • *BCT* is an effective class.

2 • If *ci* includes a Type part, the type it lists (which is *CT*) conforms to the type of the instruction's target.

3 • If *ci* has no Creation_call, then *BCT* either has no Creators part or has one that lists *dc* as one of the procedures available to *C* for creation.

4 • If *BCT* has a Creators part which doesn't list *dc*, then *ci* has a Creation_call.

5 • If *ci* has a Creation_call whose feature *f* is not *dc*, then *BCT* has a Creators part which lists *f* as one of the procedures available to *C* for creation.

6 • If *ci* has a Creation_call, that call is argument-valid.

If *CT* is a Formal_generic_name, the instruction is valid only if it satisfies the following conditions:

7 • *CT* denotes a constrained generic parameter.

8 • The Constraint for *CT* includes a Constraint_creation subclause listing one or more procedure names.

9 • If *ci* has no Creation_call, one of the listed names is the final name of *default_create* in the constraining type.

10 • If *ci* has a Creation_call, one of the listed names is the name of the feature of the Creation_call.

WARNING: *although this rule looks complicated, it is in fact just a series of consequences of a short and simple rule: the original* *"CGCI", page 436*.

The number of clauses in this second variant justifies *a contrario* using the first variant as the official definition. Fundamentally, the rule is straightforward once you have defined the "creation type", explicit or implicit and "unfolded" both the creation instruction and the creation type's base class to take care of the *default_create* convention, so that every class has a list of creation procedures and every creation instruction lists a creation procedure. Then the rule is simply that the creation type must be OK for the creation's target, that the creation procedure must be available for creation, and that the call must have valid arguments. That's all. The "corollaries" form is long because it expands the various simplifications (creation type, creation procedures of a class, creation procedure of an instruction) for the various possible cases, and treats all these cases individually — accounting for various errors that an absent-minded developer might make.

20.11 CREATION SEMANTICS

With the preceding validity rules, we can define the precise semantics of a Creation_instruction. Consider such an instruction with target *x* and creation type *TC*.

If *TC* is a **reference type**, the effect of executing the instruction is the following sequence of steps, in order:

1 • If there is not enough memory available to create a new direct instance of *TC*, trigger an exception in the routine that executed the instruction. The code for this exception is the value of the constant attribute *No_more_memory* in the Kernel Library class *EXCEPTIONS*. The remaining steps do not apply in this case.

See chapters 17 on exceptions and 34 on class EXCEPTIONS.

2 • Create a new direct instance of *TC*.

3 • Assign a value to every field of the new instance: for a field corresponding to a constant attribute, the value defined in the class text; for a field corresponding to a variable attribute, the default value of the attribute's type, according to the rules given in the next section.

→ *20.12*.

4 • Call, on the resulting object, the feature of the Unqualified_call of the instruction's unfolded form.

5 • Attach *x* to the object.

← *See 19.3, page 400 about a reference being attached to an object.*

If *TC* is an **expanded type**, the value of *x* is an object; then the effect of the instructions is to apply steps 3 and 4 above to the object attached to *x*.

Regarding step 4, remember that the notion of "unfolded form" allows us to consider that every creation instruction has an Unqualified_call; in the procedure-less form **create** *x*, this is a call to *default_create*.

← *The unfolded form of an instruction was defined on page 436.*

Also note the order of steps: attachment to the target *x* is the last operation. Until then, *x* retains its earlier value, void if *x* is a previously unattached reference.

20.12 DEFAULT INITIALIZATION VALUES

The semantic specification requires a successful Creation_instruction *always* to perform default initializations (even if they are later overridden by the creation procedure) on the new object's variable attribute fields. Here are the precise rules, which will also apply to the initialization of local entities (on every call to a routine), including the *Result* of a function.

→ *See the semantics of calls, 23.15, page 518.*

Consider a field of a newly created object, corresponding to an attribute of type *FT*. The default initialization value *init* for the field is determined as follows according to the nature of *FT*.

1 • For a reference type: a void reference.

2 • For *BOOLEAN*: the boolean value false.

3 • For *CHARACTER*: the null character.

4 • For *INTEGER*, *REAL* or *DOUBLE*: the integer, single precision or double precision zero.

5 • For *POINTER*: a null pointer.

6 • For a Bit_type of the form *BIT* N: a sequence of N zeros.

7 • If *FT* is an expanded type other than one of the basic types listed so far, *init* will be the content of a sub-object of the newly created object. To obtain *init*, apply (recursively) the default creation semantics to this sub-object, using *FT*'s version of *default_create*; the Expanded Type rule guarantees that it is indeed a creation procedure for *FT*'s base class.

← *The Expanded Type rule was on page 244.*

20.13 REMOTE CREATION

The syntax of creation instructions does not support "remote creation" instructions as in:

```
create x1.y1.cp (…)
```

***WARNING**: syntactically incorrect.*

To obtain an equivalent effect, assuming that *x1* is of type *X* and that *y1* is an attribute of type *Y* in *X*, you must introduce a specific procedure in *X*

```
make_y1 (arguments: …) is
        -- Attach y1 to new instance of Y.
    do
        create y1.cp (arguments)
    end
```

so that instead of the above attempt at remote creation clients will use the instruction

```
x1.make_y1 (…)
```

This is in line with the principle of information hiding: deciding whether or not clients of *X* may directly "create" the *y1* field is the privilege of the designer of *X* who, if the answer is positive, will write a specific procedure to grant this privilege — restricting its availability if desired.

20.14 CREATION EXPRESSIONS AND ANONYMOUS OBJECTS

We have seen all there is to see about creation instructions, but there remains to study a variant of the mechanism: creation *expressions*.

Creation expressions will provide us with *anonymous objects*. The objects that we produce with a creation instruction **create** *x*… have a name — *x* — in the software text. This is usually what we want, because after we have created the object we will start manipulating it in the same routine, or others of the same class. But in some cases the name is useless because all we do with the newly created object is to pass it to another software element. Having to declare a local entity *x* just for the purpose of a creation instruction is a nuisance. A small nuisance to be sure, but whatever the language can do to avoid writing useless elements will be good for the quality of your software and your schedule.

"Language terseness and family vacations", in SPOOF 84 (Sociology and Psychology of Object-Oriented Fanatics), Martha's Vineyard, 1999, pp. 6574-6598.

We saw an example of such a situation when examining the clonable array technique. We had the following scheme

```
figure_factory: ARRAY [FIGURE] is
        local
                fig: FIGURE
        once
                Result.make (Low_id, High_id)

                        -- Create and enter a SEGMENT instance:
                create {SEGMENT} fig.make (…)
                Result.put (fig, Segment_id)

                        -- Create and enter a TRIANGLE instance:
                create {TRIANGLE} fig.make (…)
                Result.put (fig, Triangle_id)

                … Do the same for each variant …
        end
```

← *This was example 4, page 424. See simpler formulation next.*

All we use *fig* for is to create successive objects — instances of descendants of *FIGURE*. But as soon as we have produced such an object with a creation instruction, we store it into the corresponding entry of the *Result* array (by passing it to the corresponding assignment procedure), and we will never, in this routine, need the object again! This is why we can reuse the same local entity, *fig*, for every *FIGURE* variant.

In this case the entity *fig* is not needed; neither is a separate creation instruction. All we really want is an expression denoting the new object, which we can directly pass to a routine or, as here, assign to an array element.

Creation expressions serve this need. They look like one of

```
[1]
    create {SOME_TYPE}
[2]
    create {SOME_TYPE}.creation_procedure (…)
```

The first variant, as you have guessed, is applicable if *SOME_TYPE*'s base class has no Creators part, or one that includes *default_create*; the second, if *creation_procedure* is one of its creation procedures.

Note how both variants look like a Creation_instruction:

- The first recalls the instruction **create** {*SOME_TYPE*} *target*, with no explicit Creation_call.
- The second recalls **create** {*SOME_TYPE*} *target*.*creation_procedure* (…).

You see the idea: starting from a creation instruction, you will get a creation expression simply by removing the *target* — a natural convention, since what you want is an anonymous object.

The constructs given (in any of the two forms **[1]** and **[2]**) are **expressions**, denoting values that can be assigned to a Writable entity, as in

```
x := create {SEGMENT}.make (point1, point2)
```

or, more commonly, passed as arguments to a routine, as in

Expression form.

```
segment_operation (create {SEGMENT}.make (point1, point2))
```

which has exactly the same effect as

Instruction form.

```
create {SEGMENT} seg.make (point1, point2)
segment_operation (seg)
```

with *seg* declared of type *FIGURE* (or directly of the ancestor type *SEGMENT*, in which case we can write the first line as just **create** *seg*.*make* (*point1*, *point2*)). With the creation expression we write a single call instead of three components — the declaration of *seg*, the creation instruction, and the call.

A difference with creation instructions is that for creation expressions you may not omit the Explicit_creation_type, *SOME_TYPE* or *SEGMENT* in the examples above. This is precisely because the created objects are anonymous. In the instruction **create** *target* … , if no type is specified, we use as creation type the type of *target*; but for a creation expression there is no named *target*, so you **must** specify {*SOME_TYPE*} in all cases.

Here is the clonable array extract rewritten with creation expressions:

```
figure_factory: ARRAY [FIGURE] is
    once
        Result.make (Low_id, High_id)

            -- Create and enter an instance of each desired kind:
        Result.put (create {SEGMENT}.make (…), Segment_id)
        Result.put (create {TRIANGLE}.make (…), Triangle_id)
        … Similarly for each variant …
    end
```

← The original was example 4, page 424, repeated above on page 441. To use the array, use clone operations; see

The comparison with the original form clearly shows the advantage of creation expressions in such a case. It's not so much a matter of writing *less*, since Eiffel is happy to be verbose when needed, as when specifying type properties of every entity, or expressing clear control structures. Rather, it's about avoiding elements that bring no useful information and can in fact, through their verbosity, obscure the text.

Note, however, that creation expressions are useful only in the special case of creating an object for the sole purpose of passing it to another software element, without using it further in the given routine. In every other situation — that is to say, in the vast majority of object creation needs — you should use a creation *instruction*.

So you should not be misled by the observation that you can rewrite any creation instruction

```
[3]
    create x…
```

Instruction form.

as

```
[4]
    x := create {X_TYPE} …
```

Expression form. WARNING: this is not the recommended style.

If you are going to do anything else with *x*, you should stay with the first form. If nothing else, it saves you the need to specify *X_TYPE*, which you have already specified as the type of *x* in its declaration.

In summary: reserve creation expressions for anonymous objects. This important methodological note is in line with the general Eiffel principle that the language should provide *one* good way to address any specific need. Both creation expressions and creation instructions are useful, each appropriate in a different situation.

The syntax, validity and semantics of creation expressions will now follow without further comment, since they are directly deduced from the corresponding properties of creation instructions.

Creation_expression ≜ **create** Explicit_creation_type [Explicit_creation_call]

← Explicit_creation_type, *was defined on page 435 as* {Type}.

The "creation type" and "unfolded form" of a creation expression are defined as for a creation instruction. The validity rule is also similar:

← *"Creation Instruction rule", page 436.*

Creation Expression rule *CGCE*

A Creation_expression of creation type *CT*, appearing in a class *C*, is valid if and only if it it satisfies the following two conditions:

A •The feature of the Creation_call of the instruction's unfolded form is available for creation to *C*.

B •That Creation_call is argument-valid.

Here too it is useful to have an “*only if*” version:

WARNING: *a more concise form of this rule appears just before.*

← *See “Creation Instruction rule (corollaries)”, page 438.*

Creation Expression rule (corollaries) *CGCI*

A Creation_instruction *ce* of creation type *CT*, appearing in a class *C*, is valid only if it satisfies the following conditions, assuming *CT* is not a Formal_generic_name and calling *BCT* the base class of *CT* and *dc* the version of *GENERAL*’s *default_create* in *BCT*:

1 • *BCT* is an effective class.

2 • If *ce* has no Explicit_creation_call, then *BCT* either has no Creators part or has one that lists *dc* as one of the procedures available to *C* for creation.

3 • If *BCT* has a Creators part which doesn’t list *dc*, then *ce* has an Explicit_creation_call.

4 • If *ci* has an Explicit_creation_call whose feature *f* is not *dc*, then *BCT* has a Creators part which lists *f* as one of the procedures available to *C* for creation.

5 • If *ce* has an Explicit_creation_call, that call is argument-valid.

If *CT* is a Formal_generic_name, the instruction is valid only if it satisfies the following conditions:

6 • *CT* denotes a constrained generic parameter.

7 • The Constraint for *CT* includes a Constraint_creation subclause listing one or more procedure names.

8 • If *ce* has no Explicit_creation_call, one of the listed names is the final name of *default_create* in the constraining type.

9 • If *ce* has an Explicit_creation_call, one of the listed names is the name of the feature of that call.

Finally, the semantics. The value of a creation expression of creation type *TC* is — except if step 1 below produces an exception, in which case the expression has no value — a reference to a new object if *TC* is a reference type, and a new object if *TC* is an expanded type. In either case the new object is the result of applying the following sequence of steps:

← *See “CREATION SEMANTICS”, 20.11, page 439.*

1 • If there is not enough memory available to create a new direct instance of *TC*, trigger an exception in the routine that executed the instruction. The code for this exception is the value of the constant attribute *No_more_memory* in the Kernel Library class *EXCEPTIONS*. The remaining steps do not apply in this case.

See chapters 17 on exceptions and 34 on class EXCEPTIONS.

2 • Create the desired object as a new direct instance of *TC*.

3 • Assign a value to every field of the new instance, according to the previously seen default initialization rules.

← *"DEFAULT INITIALIZATION VALUES", 20.12, page 439.*

4 • Call, on the resulting object, the feature of the Unqualified_call of the instruction's unfolded form.