ETH Zürich

Chair of Software Engineering

Einführung in die Programmierung
Introduction to Programming

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Exercise Session 4

Today

- A bit of logic
- Understanding contracts (preconditions, postconditions, and class invariants)
- Entities and objects
- Object creation

Propositional Logic

- Constants: **True**, **False**
- Atomic formulae (propositional variables): P, Q, ...
- Logical connectives: **not**, **and**, **or**, **implies**, =
- Formulae: φ, χ, ... are of the form
  - **True**
  - **False**
  - P
  - **not** φ
  - φ **and** χ
  - φ **or** χ
  - φ **implies** χ
  - φ = χ

Propositional Logic

Truth assignment and truth table

- Assigning a truth value to each propositional variable

P	Q	P implies Q
T	F	F
T	T	T
F	T	T
F	F	T

Tautology

- **True** for all truth assignments
  - P **or** (**not** P)
  - **not** (P **and** (**not** P))
  - (P **and** Q) **or** ((**not** P) **or** (**not** Q))

Contradiction

- **False** for all truth assignments
  - P **and** (**not** P)

Propositional Logic

Satisfiable

- **True** for at least one truth assignment

Equivalent

- φ and χ are equivalent if they are satisfied under exactly the same truth assignments, or if $\varphi = \chi$ is a tautology

Tautology / contradiction / satisfiable?

Hands-On

P or Q

satisfiable

P and Q

satisfiable

P or (not P)

tautology

P and (not P)

contradiction

Q implies (P and (not P))

satisfiable

Equivalence

Hands-On

Does the following equivalence hold? Prove.

(P **implies** Q) = (**not** P **implies not** Q) F

Does the following equivalence hold? Prove. T

(P **implies** Q) = (**not** Q **implies not** P)

P	Q	P implies Q	not P implies not Q	not Q implies not P
T	T	T	T	T
T	F	F	T	F
F	T	T	F	T
F	F	T	T	T

Useful stuff

De Morgan laws

not (P **or** Q) = (**not** P) **and** (**not** Q)

not (P **and** Q) = (**not** P) **or** (**not** Q)

Implications

P **implies** Q = (**not** P) **or** Q

P **implies** Q = (**not** Q) **implies** (**not** P)

Equality on Boolean expressions

(P = Q) = (P **implies** Q) **and** (Q **implies** P)

Predicate Logic

- Domain of discourse: D
- Variables: x: D
- Functions: $f: D^n \rightarrow D$
- Predicates: $P: D^n \rightarrow \{True, False\}$
- Logical connectives: **not**, **and**, **or**, **implies**, =
- Quantifiers: $\forall$, $\exists$
- Formulae: φ, χ, ... are of the form
    - $P(x, ...)$
    - **not** φ | φ **and** χ | φ **or** χ | φ **implies** χ | $\varphi = \chi$
    - $\forall x\ \varphi$
    - $\exists x\ \varphi$

Existential and universal quantification

There exists a human whose name is Bill Gates

∃ h: Human | h.name = "Bill Gates"

All persons have a name

∀ p: Person | p.name /= **Void**

Some people are students

∃ p: Person | p.is_student

The age of any person is at least 0

∀ p: Person | p.age >= 0

Nobody likes Rivella

∀ p: Person | **not** p.likes (Rivella)

not (∃ p: Person | p.likes (Rivella))

Tautology / contradiction / satisfiable?

Hands-On

Let the domain of discourse be INTEGER

$x < 0$ **or** $x >= 0$

tautology

$x > 0$ **implies** $x > 1$

satisfiable

$\forall x \mid x > 0$ **implies** $x > 1$

contradiction

$\forall x \mid x * y = y$

satisfiable

$\exists y \mid \forall x \mid x * y = y$

tautology

Semi-strict operations

Semi-strict operators (**and then**, **or else**)

- *a* **and then** *b*

  has same value as *a* **and** *b* if *a* and *b* are defined, and has value **False** whenever *a* has value **False**.

  text /= **Void and then** *text.contains* ("Joe")

- *a* **or else** *b*

  has same value as *a* **or** *b* if *a* and *b* are defined, and has value **True** whenever *a* has value **True**.

  list = **Void or else** *list.is_empty*

Strict or semi-strict?

Hands-On

- *a* = 0 **or** *b* = 0
- *a* /= 0 **and** *b* // *a* /= 0
- *a* /= **Void** **and** *b* /= **Void**
- *a* < 0 **or** *sqrt* (*a*) > 2
- (*a* = *b* **and** *b* /= **Void**) **and** **not** *a.name* .is_equal ("")

Assertions

$$\underbrace{\overbrace{\text{balance\_non\_negative:}}^{\text{Assertion }\textbf{tag}\text{ (not required, but recommended)}}\ \overbrace{\mathit{balance} >= 0}^{\textbf{Condition}\text{ (required)}}}_{\textbf{Assertion clause}}$$

Precondition

Property that a feature imposes on every client

```
clap (n: INTEGER)
        -- Clap n times and update count.
    require
        not_too_tired: count <= 10
        n_positive: n > 0
```

A feature with no **require** clause is always applicable, as if the precondition reads

```
require
    always_OK: True
```

Postcondition

Property that a feature guarantees on termination

```
clap (n: INTEGER)
        -- Clap n times and update count.
    require
        not_too_tired: count <= 10
        n_positive: n > 0
    ensure
        count_updated: count = old count + n
```

A feature with no **ensure** clause always satisfies its postcondition, as if the postcondition reads

```
    ensure
        always_OK: True
```

Class Invariant

Property that is true of the current object at any observable point

```
class ACROBAT
    …
invariant
    count_non_negative: count >= 0
end
```

A class with no **invariant** clause has a trivial invariant

```
always_OK: True
```

Pre- and postcondition example

Hands-On

Add pre- and postconditions to:

```
smallest_power (n, bound: NATURAL): NATURAL
        -- Smallest x such that `n'^x is greater or equal `bound'.
    require
        ???
    do
        ...
    ensure
        ???
    end
```

One possible solution


```
smallest_power (n, bound: NATURAL): NATURAL
        -- Smallest x such that `n'^x is greater or equal `bound'.
    require
        n_large_enough: n > 1
        bound_large_enough: bound > 1
    do
        ...
    ensure
        greater_equal_bound: n ^ Result >= bound
        smallest: n ^ (Result - 1) < bound
    end
```

Hands-on exercise

Hands-On

Add invariants to classes *ACROBAT_WITH_BUDDY* and *CURMUDGEON*.

Add preconditions and postconditions to feature *make* in *ACROBAT_WITH_BUDDY*.

Class *ACROBAT_WITH_BUDDY*

```
class
    ACROBAT_WITH_BUDDY

inherit
    ACROBAT
        redefine
            twirl, clap, count
        end

create
    make

feature
    make (p: ACROBAT)
        do
            -- Remember `p' being
            -- the buddy.
        end

    clap (n: INTEGER)
        do
            -- Clap `n' times and
            -- forward to buddy.
        end

    twirl (n: INTEGER)
        do
            -- Twirl `n' times and
            -- forward to buddy.
        end

    count: INTEGER
        do
            -- Ask buddy and return his
            -- answer.
        end

    buddy: ACROBAT
end
```

Class *CURMUDGEON*

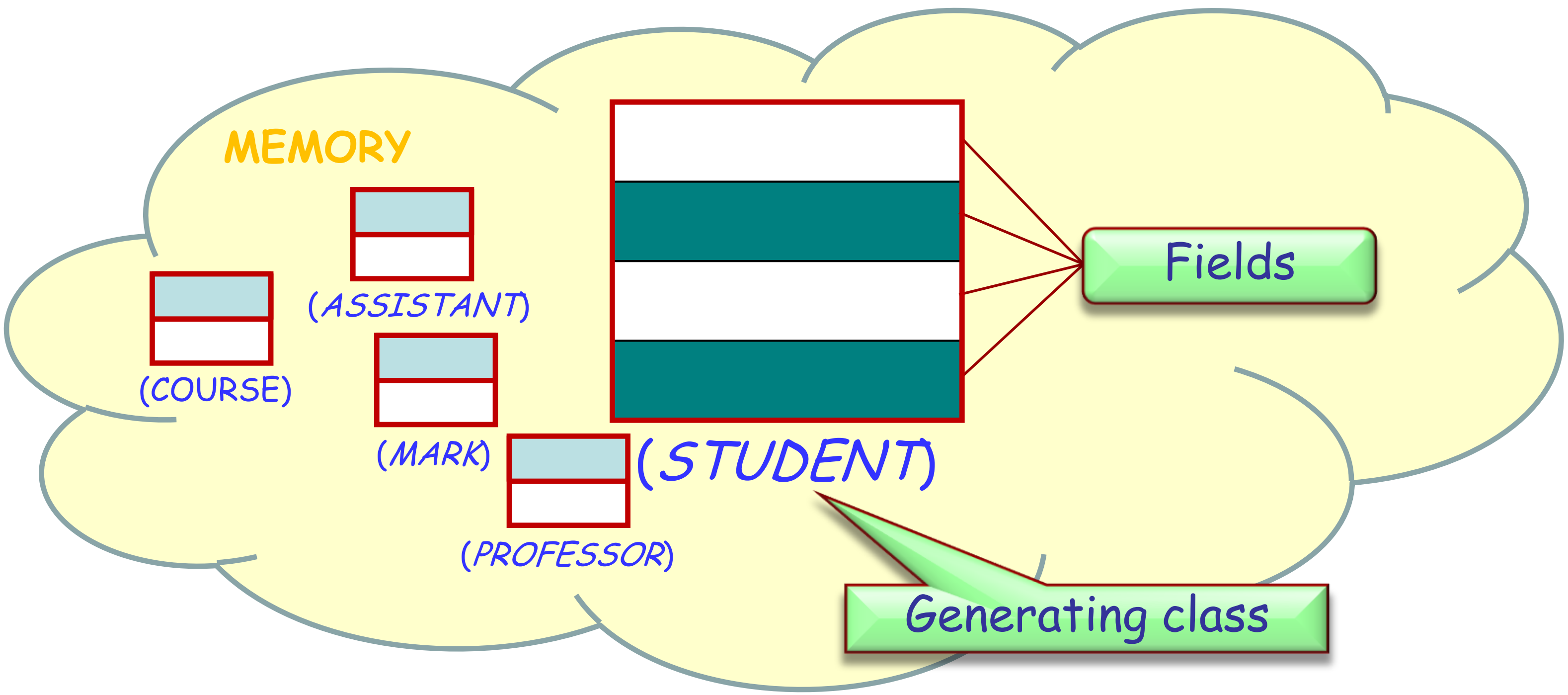
```
class
    CURMUDGEON

inherit
    ACROBAT
        redefine clap, twirl end

feature
    clap (n: INTEGER)
        do
            -- Say “I refuse”.
        end

    twirl (n: INTEGER)
        do
            -- Say “I refuse”.
        end
end
```

Entity vs. object

In the class text: **an entity**

joe: STUDENT

In memory, during execution: **an object**

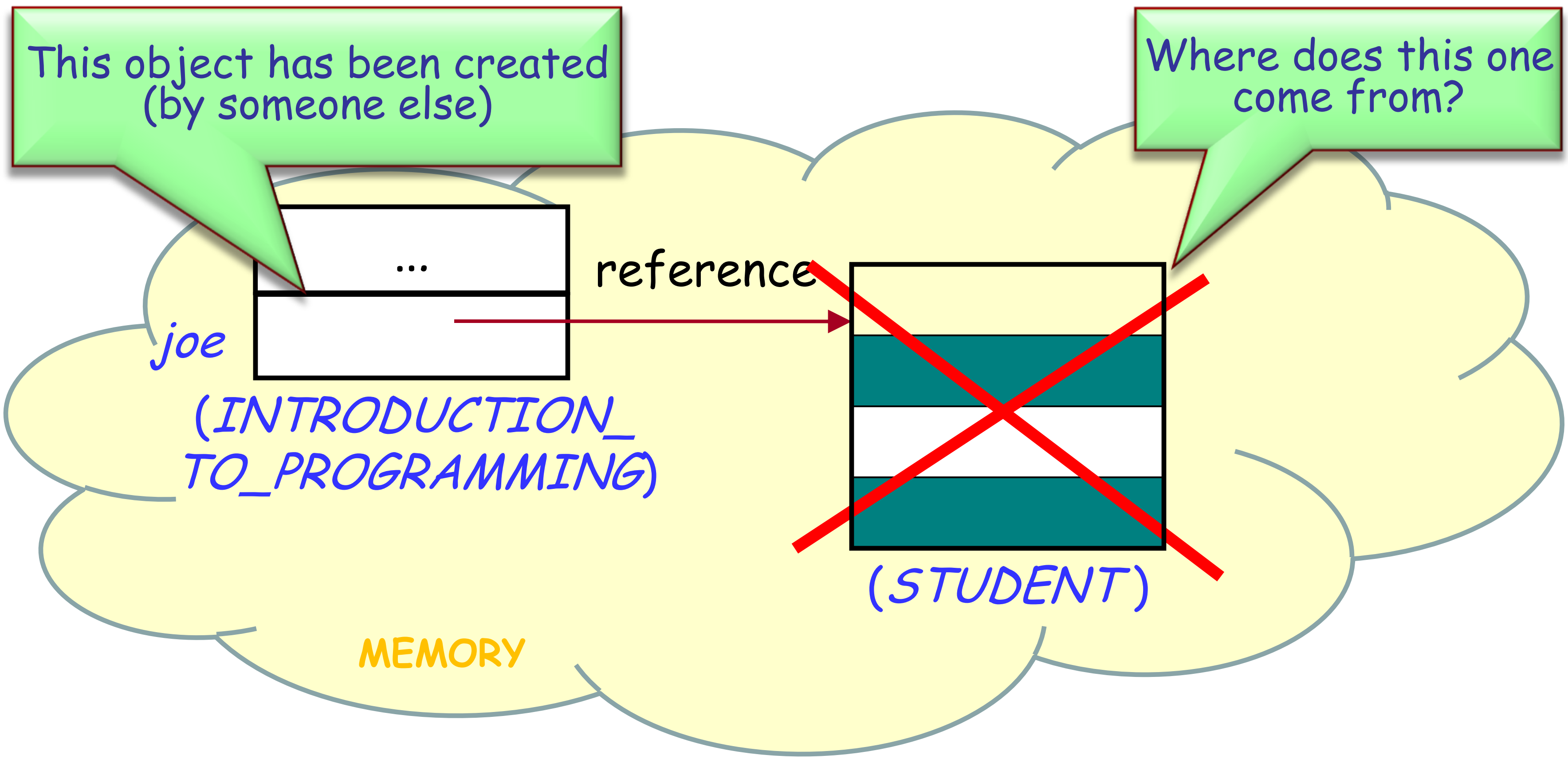


INTRODUCTION_TO_PROGRAMMING

```
class
        INTRODUCTION_TO_PROGRAMMING
inherit
        COURSE
feature
        execute
                        -- Teach `joe' programming.
                do
                        -- ???
                        joe.solve_all_assignments
                end

        joe: STUDENT
                -- A first year computer science student
end
```

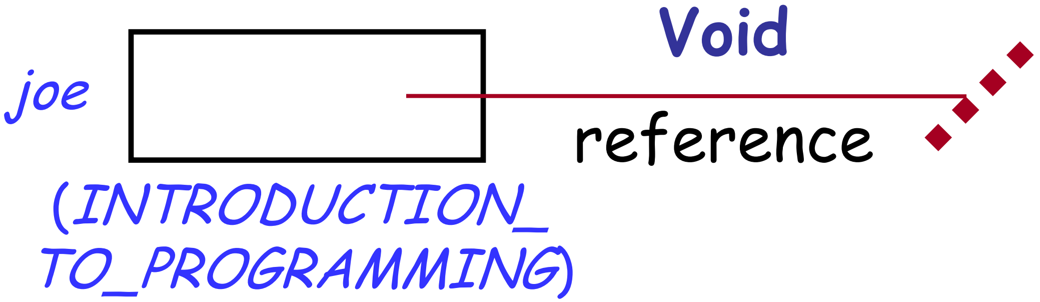
Initial state of a reference

In an instance of *INTRODUCTION_TO_PROGRAMMING*, may we assume that *joe* is attached to an instance of *STUDENT*?



By default

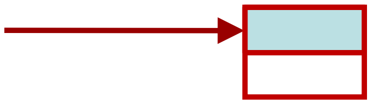
Initially, *joe* is not attached to any object:
its value is a **Void** reference.



States of an entity

During execution, an entity can:

- Be **attached** to a certain object



- Have the value **Void**

States of an entity

- To denote a void reference: use **Void** keyword
- To create a new object in memory and attach x to it: use **create** keyword

create x

- To find out if x is void: use the expressions

x = **Void** (true iff x is void)

x /= **Void** (true iff x is attached)

Those mean void references!

The basic mechanism of computation is feature call

Apply feature *f*

$x.f\,(a, \ldots)$

To object to which *x* is attached

Possibly with arguments

Since references may be void, *x* might be attached to no object

The call is erroneous in such cases!

Why do we need to create objects?

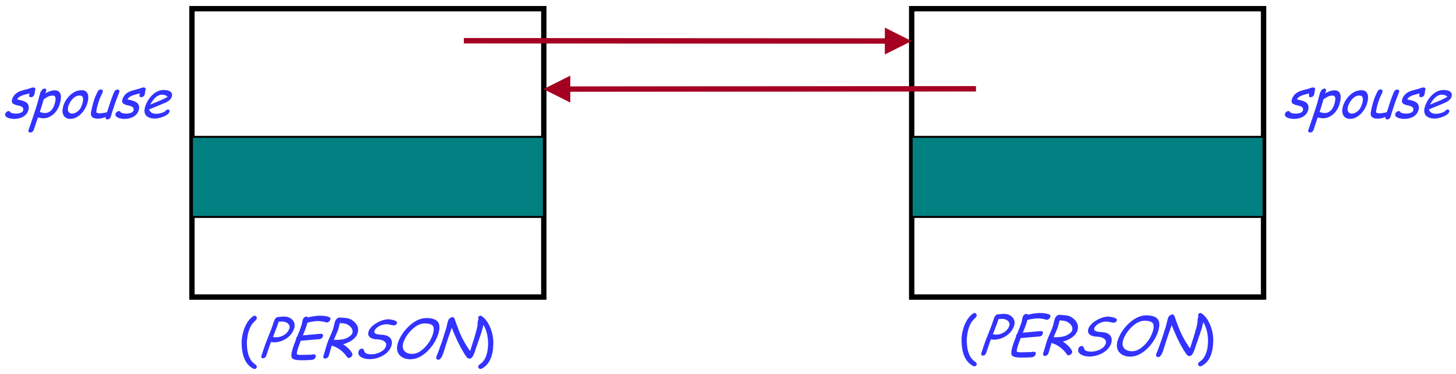
Shouldn't we assume that a declaration

joe: *STUDENT*

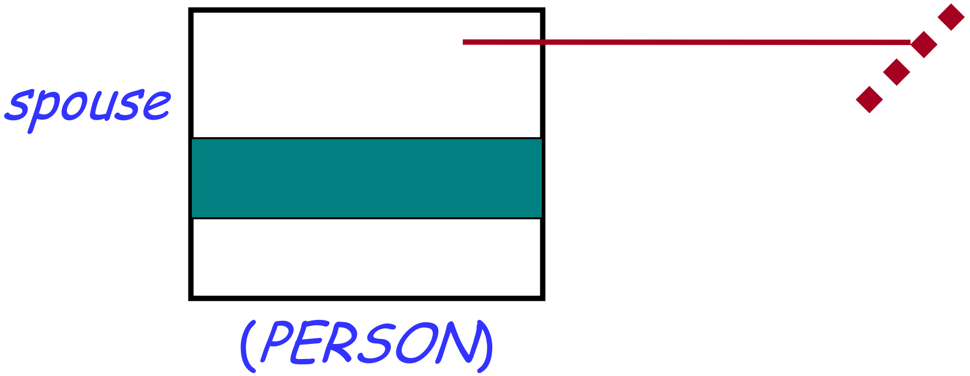
creates an instance of *STUDENT* and attaches it to *joe*?

Those wonderful void references!

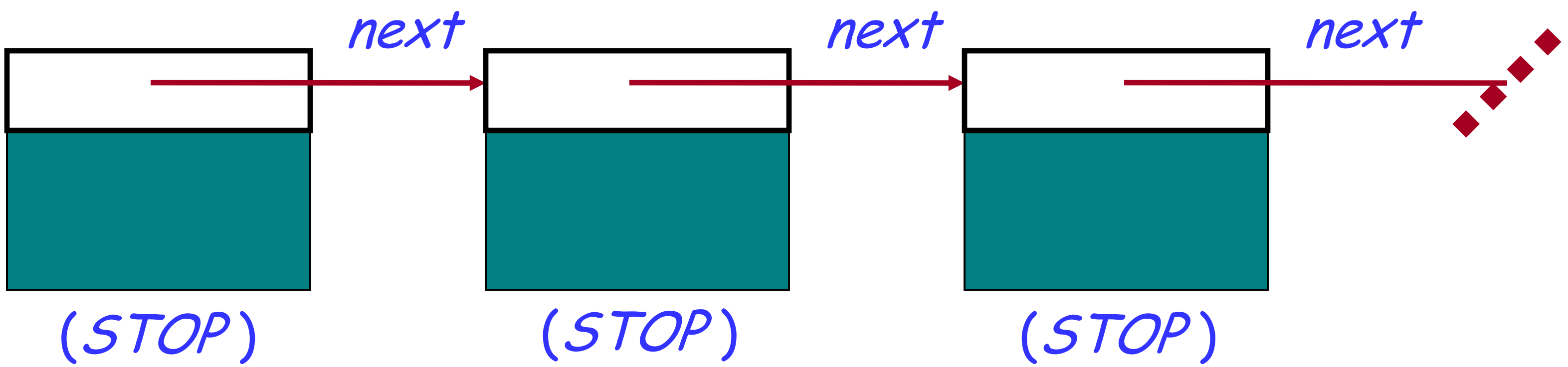
Married persons:



Unmarried person:



Those wonderful void references!

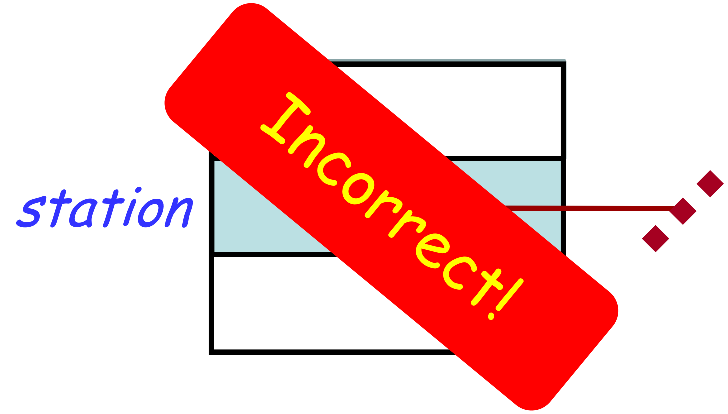


Last *next* reference is void to terminate the list.

Creation procedures

- Instruction **create** *x* will initialize all the fields of the new object attached to *x* with default values
- What if we want some specific initialization? E.g., to make object consistent with its class invariant?

```
class STOP
...
        station: STATION
invariant
        station /= Void
```



- Use creation procedure:

create *stop1.set_station (Central)*

STOP

```
class STOP
create
    set_station
feature
    station: STATION
            -- Station which this stop represents
    next: SIMPLE_STOP
            -- Next stop on the same line
    set_station (s: STATION)
            -- Associate this stop with s.
        require
                station_exists: s /= Void
        ensure
                station_set: station = s
    link (s: SIMPLE_STOP)
            -- Make s the next stop on the line.
        ensure
                next_set: next = s
invariant
    station_exists: station /= Void
end
```

List one or more creation procedures

May be used as a regular command and as a creation procedure

Is established by *set_station*

Object creation: summary

To create an object:

- If class has no **create** clause, use basic form:

  create *x*

- If the class has a **create** clause listing one or more procedures, use

  create *x.make* (...)

  where *make* is one of the creation procedures, and (...) stands for arguments if any.

Some acrobatics

Hands-On

```
class DIRECTOR
create prepare_and_play
feature
    acrobat1, acrobat2, acrobat3: ACROBAT
    friend1, friend2: ACROBAT_WITH_BUDDY
    author1: AUTHOR
    curmudgeon1: CURMUDGEON

    prepare_and_play
            do
                author1.clap (4)
                friend1.twirl (2)
                curmudgeon1.clap (7)
                acrobat2.clap (curmudgeon1.count)
                acrobat3.twirl (friend2.count)
                friend1.buddy.clap (friend1.count)
                friend2.clap (2)
            end
end
```

What entities are used in this class?

What's wrong with the feature *prepare_and_play*?

Some acrobatics

Hands-On

```
class DIRECTOR
create prepare_and_play
feature
    acrobat1, acrobat2, acrobat3: ACROBAT
    friend1, friend2: ACROBAT_WITH_BUDDY
    author1: AUTHOR
    curmudgeon1: CURMUDGEON

    prepare_and_play
            do
1               create acrobat1
2               create acrobat2
3               create acrobat3
4               create friend1.make_with_buddy (acrobat1)
5               create friend2.make_with_buddy (friend1)
6               create author1
7               create curmudgeon1
            end
end
```

Which entities are still **Void** after execution of line 4?

Which of the classes mentioned here have creation procedures?

Why is the creation procedure necessary?