

Syntax of Eiffel: a Brief Overview



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Escape Sequences



Escape sequences are special characters to be placed in your program text.

- In Java, an escape sequence starts with a backward slash \
e.g., `\n` for a new line character.
- In Eiffel, an escape sequence starts with a percentage sign %
e.g., `%N` for a new line character.

See here for more escape sequences in Eiffel: https://www.eiffel.org/doc/eiffel/Eiffel%20programming%20language%20syntax#Special_characters

Commands, and Queries, and Features



- In a Java class:
 - **Attributes:** Data
 - **Mutators:** Methods that change attributes without returning
 - **Accessors:** Methods that access attribute values and returning
- In an Eiffel class:
 - Everything can be called a *feature*.
 - But if you want to be specific:
 - Use *attributes* for data
 - Use *commands* for mutators
 - Use *queries* for accessors

Naming Conventions



- Cluster names: all lower-cases separated by underscores
e.g., `root, model, tests, cluster_number_one`
- Classes/Type names: all upper-cases separated by underscores
e.g., `ACCOUNT, BANK_ACCOUNT_APPLICATION`
- Feature names (attributes, commands, and queries): all lower-cases separated by underscores
e.g., `account_balance, deposit_into, withdraw_from`

Class Declarations



- In Java:

```
class BankAccount {
  /* attributes and methods */
}
```

- In Eiffel:

```
class BANK_ACCOUNT
  /* attributes, commands, and queries */
end
```

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Creations of Objects (1)



- In Java, we use a constructor `Account (int b)` by:
 - Writing `Account acc = new Account (10)` to create a named object `acc`
 - Writing `new Account (10)` to create an anonymous object
- In Eiffel, we use a creation feature (i.e., a command explicitly declared under `create`) `make (int b)` in class `ACCOUNT` by:

- Writing `create {ACCOUNT} acc.make (10)` to create a named object `acc`
- Writing `create {ACCOUNT}.make (10)` to create an anonymous object

- Writing `create {ACCOUNT} acc.make (10)`

is really equivalent to writing

```
acc := create {ACCOUNT}.make (10)
```

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Class Constructor Declarations (1)



- In Eiffel, constructors are just commands that have been *explicitly* declared as **creation features**:

```
class BANK_ACCOUNT
  -- List names commands that can be used as constructors
  create
    make
  feature -- Commands
    make (b: INTEGER)
      do balance := b end
    make2
      do balance := 10 end
  end
```

- Only the command `make` can be used as a constructor.
- Command `make2` is not declared explicitly, so it cannot be used as a constructor.

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Attribute Declarations



- In Java, you write: `int i, Account acc`
- In Eiffel, you write: `i: INTEGER, acc: ACCOUNT`
Think of `:` as the set membership operator \in :
e.g., The declaration `acc: ACCOUNT` means object `acc` is a member of all possible instances of `ACCOUNT`.

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Method Declaration



- **Command**

```
deposit (amount: INTEGER)
do
  balance := balance + amount
end
```

Notice that you don't use the return type `void`

- **Query**

```
sum_of (x: INTEGER; y: INTEGER): INTEGER
do
  Result := x + y
end
```

- Input parameters are separated by semicolons ;
- Notice that you don't use `return`; instead assign the return value to the pre-defined variable **Result**.

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Operators: Division and Modulo



	Division	Modulo (Remainder)
Java	20 / 3 is 6	20 % 3 is 2
Eiffel	20 // 3 is 6	20 \ \ 3 is 2

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Operators: Assignment vs. Equality



- In Java:
 - Equal sign = is for assigning a value expression to some variable.
e.g., `x = 5 * y` changes `x`'s value to `5 * y`
This is actually controversial, since when we first learned about =, it means the mathematical equality between numbers.
 - Equal-equal == and bang-equal != are used to denote the equality and inequality.
e.g., `x == 5 * y` evaluates to *true* if `x`'s value is equal to the value of `5 * y`, or otherwise it evaluates to *false*.
- In Eiffel:
 - Equal = and slash equal /= denote equality and inequality.
e.g., `x = 5 * y` evaluates to *true* if `x`'s value is equal to the value of `5 * y`, or otherwise it evaluates to *false*.
 - We use := to denote variable assignment.
e.g., `x := 5 * y` changes `x`'s value to `5 * y`
 - Also, you are not allowed to write shorthands like `x++`, just write `x := x + 1`.

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Operators: Logical Operators (1)



- Logical operators (what you learned from EECS1090) are for combining Boolean expressions.
- In Eiffel, we have operators that **EXACTLY** correspond to these logical operators:

	LOGIC	EIFFEL
Conjunction	∧	and
Disjunction	∨	or
Implication	⇒	implies
Equivalence	≡	=

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Operators: Logical Operators (2)

- How about Java?
 - Java does not have an operator for logical implication.
 - The == operator can be used for logical equivalence.
 - The && and || operators only **approximate** conjunction and disjunction, due to the **short-circuit effect (SCE)**:
 - When evaluating $e1 \ \&\& \ e2$, if $e1$ already evaluates to **false**, then $e2$ will **not** be evaluated.
 - e.g., In $(y \neq 0) \ \&\& \ (x / y > 10)$, the SCE guards the division against division-by-zero error.
 - When evaluating $e1 \ || \ e2$, if $e1$ already evaluates to **true**, then $e2$ will **not** be evaluated.
 - e.g., In $(y == 0) \ || \ (x / y > 10)$, the SCE guards the division against division-by-zero error.
 - However, in math, the order of the two sides should not matter.
- In Eiffel, we also have the version of operators with SCE:

	short-circuit conjunction	short-circuit disjunction
Java	&&	
Eiffel	and then	or else

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Selections (2)

- An **if-statement** is considered as:
- An **instruction** if its branches contain **instructions**.
 - An **expression** if its branches contain Boolean **expressions**.

```
class
  FOO
  feature --Attributes
    x, y: INTEGER
  feature -- Commands
    command
      -- A command with if-statements in implementation and contracts.
      require
        if x \ 2 /= 0 then True else False end -- Or: x \ 2 /= 0
      do
        if x > 0 then y := 1 elseif x < 0 then y := -1 else y := 0 end
      ensure
        y = if old x > 0 then 1 elseif old x < 0 then -1 else 0 end
        -- Or: (old x > 0 implies y = 1)
        -- and (old x < 0 implies y = -1) and (old x = 0 implies y = 0)
      end
    end
end
```

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Selections (1)

```
if B1 then
  -- B1
  -- do something
elseif B2 then
  -- B2 ∧ (¬B1)
  -- do something else
else
  -- (¬B1) ∧ (¬B2)
  -- default action
end
```

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Loops (1)

- In Java, the Boolean conditions in for and while loops are **stay** conditions.

```
void printStuffs() {
  int i = 0;
  while (i < 10 /* stay condition */) {
    System.out.println(i);
    i = i + 1;
  }
}
```

- In the above Java loop, we **stay** in the loop as long as $i < 10$ is true.
- In Eiffel, we think the opposite: we **exit** the loop as soon as $i \geq 10$ is true.

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Loops (2)

In Eiffel, the Boolean conditions you need to specify for loops are **exit** conditions (logical negations of the stay conditions).

```
print_stuffs
local
  i: INTEGER
do
  from
    i := 0
  until
    i >= 10 -- exit condition
  loop
    print (i)
    i := i + 1
  end -- end loop
end -- end command
```

- Don't put () after a command or query with no input parameters.
- Local variables must all be declared in the beginning.

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Data Structures: Arrays

- Creating an empty array:

```
local a: ARRAY[INTEGER]
do create {ARRAY[INTEGER]} a.make_empty
```

- This creates an array of lower and upper indices 1 and 0.
- Size of array a: $a.upper - a.lower + 1$.

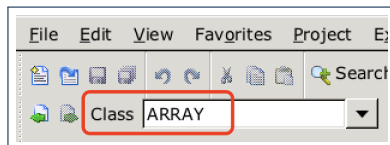
- Typical loop structure to iterate through an array:

```
local
  a: ARRAY[INTEGER]
  i, j: INTEGER
do
  ...
  from
    j := a.lower
  until
    j > a.upper
  do
    i := a [j]
    j := j + 1
  end
```

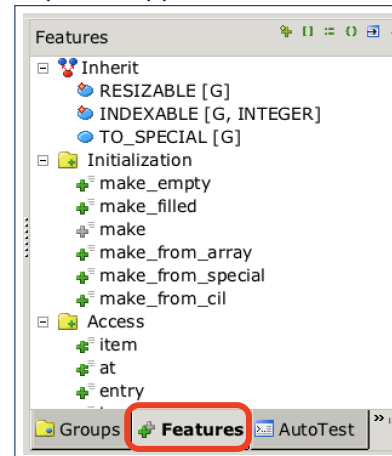
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Library Data Structures

Enter a DS name.

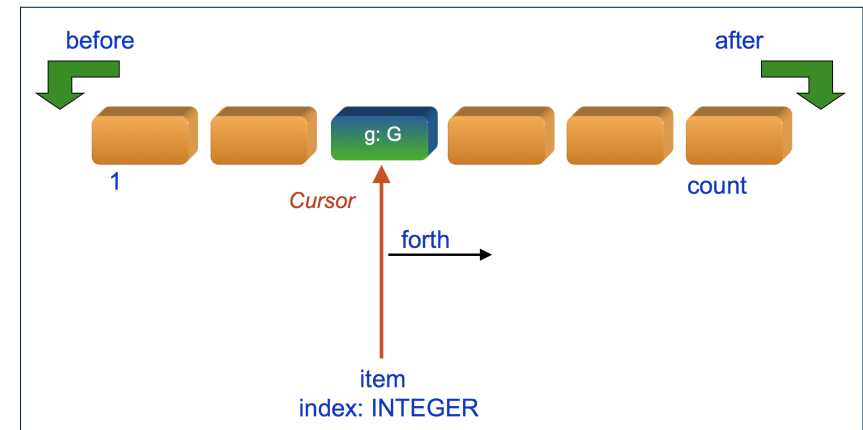


Explore supported features.



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Data Structures: Linked Lists (1)



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Data Structures: Linked Lists (2)



- Creating an empty linked list:

```
local
  list: LINKED_LIST[INTEGER]
do
  create {LINKED_LIST[INTEGER]} list.make
```

- Typical loop structure to iterate through a linked list:

```
local
  list: LINKED_LIST[INTEGER]
  i: INTEGER
do
  ...
from
  list.start
until
  list.after
do
  i := list.item
  list.forth
end
```

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Using across for Quantifications (1.1)



- **across** ... **as** ... **all** ... **end**

A Boolean expression acting as a universal quantification (\forall)

```
1 local
2   allPositive: BOOLEAN
3   a: ARRAY[INTEGER]
4 do
5   ...
6   Result :=
7     across
8       a.lower |..| a.upper as i
9     all
10      a [i.item] > 0
11   end
```

- **L8**: `a.lower |..| a.upper` denotes a list of integers.
- **L8**: `as i` declares a list cursor for this list.
- **L10**: `i.item` denotes the value pointed to by cursor `i`.
- **L9**: Changing the keyword **all** to **some** makes it act like an existential quantification \exists .

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Iterable Structures



- Eiffel collection types (like in Java) are **iterable**.
- If indices are irrelevant for your application, use:

across ... **as** ... **loop** ... **end**

e.g.,

```
...
local
  a: ARRAY[INTEGER]
  l: LINKED_LIST[INTEGER]
  sum1, sum2: INTEGER
do
  ...
  across a as cursor loop sum1 := sum1 + cursor.item end
  across l as cursor loop sum2 := sum2 + cursor.item end
  ...
end
```

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Using across for Quantifications (1.2)



- Alternatively: **across** ... **is** ... **all** ... **end**

A Boolean expression acting as a universal quantification (\forall)

```
1 local
2   allPositive: BOOLEAN
3   a: ARRAY[INTEGER]
4 do
5   ...
6   Result :=
7     across
8       a.lower |..| a.upper is i
9     all
10      a [i] > 0
11   end
```

- **L8**: `a.lower |..| a.upper` denotes a list of integers.
- **L8**: `is i` declares a variable for storing a member of the list.
- **L10**: `i` denotes the value itself.
- **L9**: Changing the keyword **all** to **some** makes it act like an existential quantification \exists .

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Using across for Quantifications (2)



```
class
  CHECKER
  feature -- Attributes
    collection: ITERABLE [INTEGER] -- ARRAY, LIST, HASH_TABLE
  feature -- Queries
    is_all_positive: BOOLEAN
    -- Are all items in collection positive?
  do
    ...
  ensure
    across
      collection as cursor
    all
      cursor.item > 0
    end
  end
end
```

- Using **all** corresponds to a universal quantification (i.e., \forall).
- Using **some** corresponds to an existential quantification (i.e., \exists).

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Using across for Quantifications (4)



```
class BANK
...
  accounts: LIST [ACCOUNT]
  contains_duplicate: BOOLEAN
  -- Does the account list contain duplicate?
  do
    ...
  ensure
     $\forall i, j: \text{INTEGER} \mid$ 
       $1 \leq i \leq \text{accounts.count} \wedge 1 \leq j \leq \text{accounts.count} \bullet$ 
       $\text{accounts}[i] \sim \text{accounts}[j] \Rightarrow i = j$ 
  end
```

- **Exercise:** Convert this mathematical predicate for postcondition into Eiffel.
- **Hint:** Each **across** construct can only introduce one dummy variable, but you may nest as many **across** constructs as necessary.

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Using across for Quantifications (3)



```
class BANK
...
  accounts: LIST [ACCOUNT]
  binary_search (acc_id: INTEGER): ACCOUNT
  -- Search on accounts sorted in non-descending order.
  require
    --  $\forall i: \text{INTEGER} \mid 1 \leq i < \text{accounts.count} \bullet \text{accounts}[i].\text{id} \leq \text{accounts}[i+1].\text{id}$ 
  across
    1 |..| (accounts.count - 1) as cursor
  all
    accounts [cursor.item].id <= accounts [cursor.item + 1].id
  end
  do
    ...
  ensure
    Result.id = acc_id
  end
end
```

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Equality



- To compare references between two objects, use =.
- To compare “contents” between two objects *of the same type*, use the *redefined* version of is_equal feature.
- You may also use the binary operator \sim
 - o1 \sim o2 evaluates to:
 - o true if both o1 and o2 are void
 - o false if one is void but not the other
 - o o1.is_equal(o2) if both are not void

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Use of ~: Caution

```

1 class
2   BANK
3   feature -- Attribute
4     accounts: ARRAY[ACCOUNT]
5   feature -- Queries
6     get_account (id: STRING): detachable ACCOUNT
7       -- Account object with 'id'.
8     do
9       across
10        accounts as cursor
11      loop
12        if cursor.item ~ id then
13          Result := cursor.item
14        end
15      end
16    end
17  end
  
```

L15 should be: `cursor.item.id ~ id`

Review of Propositional Logic: Implication

- Written as $p \Rightarrow q$
- Pronounced as “p implies q”
- We call p the antecedent, assumption, or premise.
- We call q the consequence or conclusion.
- Compare the *truth* of $p \Rightarrow q$ to whether a contract is *honoured*: $p \approx$ promised terms; and $q \approx$ obligations.
- When the promised terms are met, then:
 - The contract is *honoured* if the obligations are fulfilled.
 - The contract is *breached* if the obligations are not fulfilled.
- When the promised terms are not met, then:
 - Fulfilling the obligation (q) or not ($\neg q$) does *not breach* the contract.

p	q	$p \Rightarrow q$
true	true	true
true	false	false
false	true	true
false	false	true

Review of Propositional Logic (1)

- A **proposition** is a statement of claim that must be of either *true* or *false*, but not both.
- Basic logical operands are of type Boolean: *true* and *false*.
- We use logical operators to construct compound statements.
 - Binary logical operators: conjunction (\wedge), disjunction (\vee), implication (\Rightarrow), and equivalence (a.k.a if-and-only-if \Leftrightarrow)

p	q	$p \wedge q$	$p \vee q$	$p \Rightarrow q$	$p \Leftrightarrow q$
true	true	true	true	true	true
true	false	false	true	false	false
false	true	false	true	true	false
false	false	false	false	true	true

- Unary logical operator: negation (\neg)

p	$\neg p$
true	false
false	true

Review of Propositional Logic (2)

- Axiom:** Definition of \Rightarrow

$$p \Rightarrow q \equiv \neg p \vee q$$

- Theorem:** Identity of \Rightarrow

$$\text{true} \Rightarrow p \equiv p$$

- Theorem:** Zero of \Rightarrow

$$\text{false} \Rightarrow p \equiv \text{true}$$

- Axiom:** De Morgan

$$\neg(p \wedge q) \equiv \neg p \vee \neg q$$

$$\neg(p \vee q) \equiv \neg p \wedge \neg q$$

- Axiom:** Double Negation

$$p \equiv \neg(\neg p)$$

- Theorem:** Contrapositive

$$p \Rightarrow q \equiv \neg q \Rightarrow \neg p$$

Review of Predicate Logic (1)

- A **predicate** is a *universal* or *existential* statement about objects in some universe of disclosure.
- Unlike propositions, predicates are typically specified using *variables*, each of which declared with some *range* of values.
- We use the following symbols for common numerical ranges:
 - \mathbb{Z} : the set of integers
 - \mathbb{N} : the set of natural numbers
- Variable(s) in a predicate may be *quantified*:
 - **Universal quantification**:
All values that a variable may take satisfy certain property.
e.g., Given that i is a natural number, i is *always* non-negative.
 - **Existential quantification**:
Some value that a variable may take satisfies certain property.
e.g., Given that i is an integer, i *can be* negative.

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Review of Predicate Logic (2.2)

- An **existential quantification** has the form $(\exists X \mid R \bullet P)$
 - X is a list of variable *declarations*
 - R is a *constraint on ranges* of declared variables
 - P is a *property*
 - $(\exists X \mid R \bullet P) \equiv (\exists X \bullet R \wedge P)$
e.g., $(\exists X \mid \text{True} \bullet P) \equiv (\exists X \bullet \text{True} \wedge P) \equiv (\exists X \bullet P)$
 - e.g., $(\exists X \mid \text{False} \bullet P) \equiv (\exists X \bullet \text{False} \wedge P) \equiv (\exists X \bullet \text{False}) \equiv \text{False}$
- **There exists** a combination of values of variables declared in X that satisfies R and P .
 - $\exists i \mid i \in \mathbb{N} \bullet i \geq 0$ [true]
 - $\exists i \mid i \in \mathbb{Z} \bullet i \geq 0$ [true]
 - $\exists i, j \mid i \in \mathbb{Z} \wedge j \in \mathbb{Z} \bullet i < j \vee i > j$ [true]
- The range constraint of a variable may be moved to where the variable is declared.
 - $\exists i: \mathbb{N} \bullet i \geq 0$
 - $\exists i: \mathbb{Z} \bullet i \geq 0$
 - $\exists i, j: \mathbb{Z} \bullet i < j \vee i > j$

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Review of Predicate Logic (2.1)

- A **universal quantification** has the form $(\forall X \mid R \bullet P)$
 - X is a list of variable *declarations*
 - R is a *constraint on ranges* of declared variables
 - P is a *property*
 - $(\forall X \mid R \bullet P) \equiv (\forall X \bullet R \Rightarrow P)$
e.g., $(\forall X \mid \text{True} \bullet P) \equiv (\forall X \bullet \text{True} \Rightarrow P) \equiv (\forall X \bullet P)$
 - e.g., $(\forall X \mid \text{False} \bullet P) \equiv (\forall X \bullet \text{False} \Rightarrow P) \equiv (\forall X \bullet \text{True}) \equiv \text{True}$
- **For all** (combinations of) values of variables declared in X that satisfies R , it is the case that P is satisfied.
 - $\forall i \mid i \in \mathbb{N} \bullet i \geq 0$ [true]
 - $\forall i \mid i \in \mathbb{Z} \bullet i \geq 0$ [false]
 - $\forall i, j \mid i \in \mathbb{Z} \wedge j \in \mathbb{Z} \bullet i < j \vee i > j$ [false]
- The range constraint of a variable may be moved to where the variable is declared.
 - $\forall i: \mathbb{N} \bullet i \geq 0$
 - $\forall i: \mathbb{Z} \bullet i \geq 0$
 - $\forall i, j: \mathbb{Z} \bullet i < j \vee i > j$

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Predicate Logic (3)

- Conversion between \forall and \exists

$$\begin{aligned} (\forall X \mid R \bullet P) &\iff \neg(\exists X \bullet R \Rightarrow \neg P) \\ (\exists X \mid R \bullet P) &\iff \neg(\forall X \bullet R \Rightarrow \neg P) \end{aligned}$$

- Range Elimination

$$\begin{aligned} (\forall X \mid R \bullet P) &\iff (\forall X \bullet R \Rightarrow P) \\ (\exists X \mid R \bullet P) &\iff (\exists X \bullet R \wedge P) \end{aligned}$$

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