Item 0: Introduction and definitions

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Grado en Ingeniería Informática

Curso 2018/2019

Topics

1. Introduction
2. Translator / compiler concept and types
3. Compiler execution enviroment
4. Stages of a compiler
5. Scanning
6. Parsing
7. Semantic analysis
8. Code generation
9. Other stages

Introduction

Abstraction effort

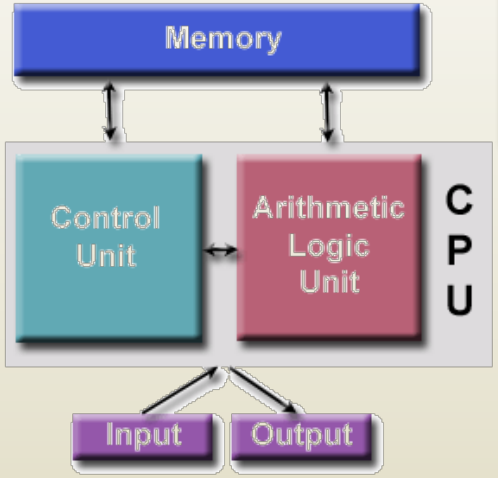
- Programming history can be described as a constant effort to bring the executable language of hardware architectures to a more close human language through successive steps of abstraction

Abstraction effort

Von Neumann architectures

- Program representation as instructions in memory
- The control unit is sequentially reading the program
- Each instruction has an operation code and operands
- Arithmetic logic operations, comparative operations, jump operations, I/O operations …

Operation code	Operating 1	Operating 2
11100110	0001	0110
10101001	1100	0011
11000011	1101	1100



Low level

Abstraction level

1945
```
11100110 0001 0110
10101001 1100 0011
11000011 1101 1100
```

1950
```
MOVE AX #2
MOVE BX #3
MUL CX AX BX
```

1968
```
fact = 1;
for i := 0 to 10
   fact := fact * i;
```

1970
```
wait(q);
i:= fact(x);
signal(q);
```

1990
```
fun mul (x, y) = x*y
fun fact (n, m) =
   0 -> 1
   | m (n, fact (n-1, m))
```

1995
```
Class Punto {
    int x, y;
    int modulo () {...}
}
```

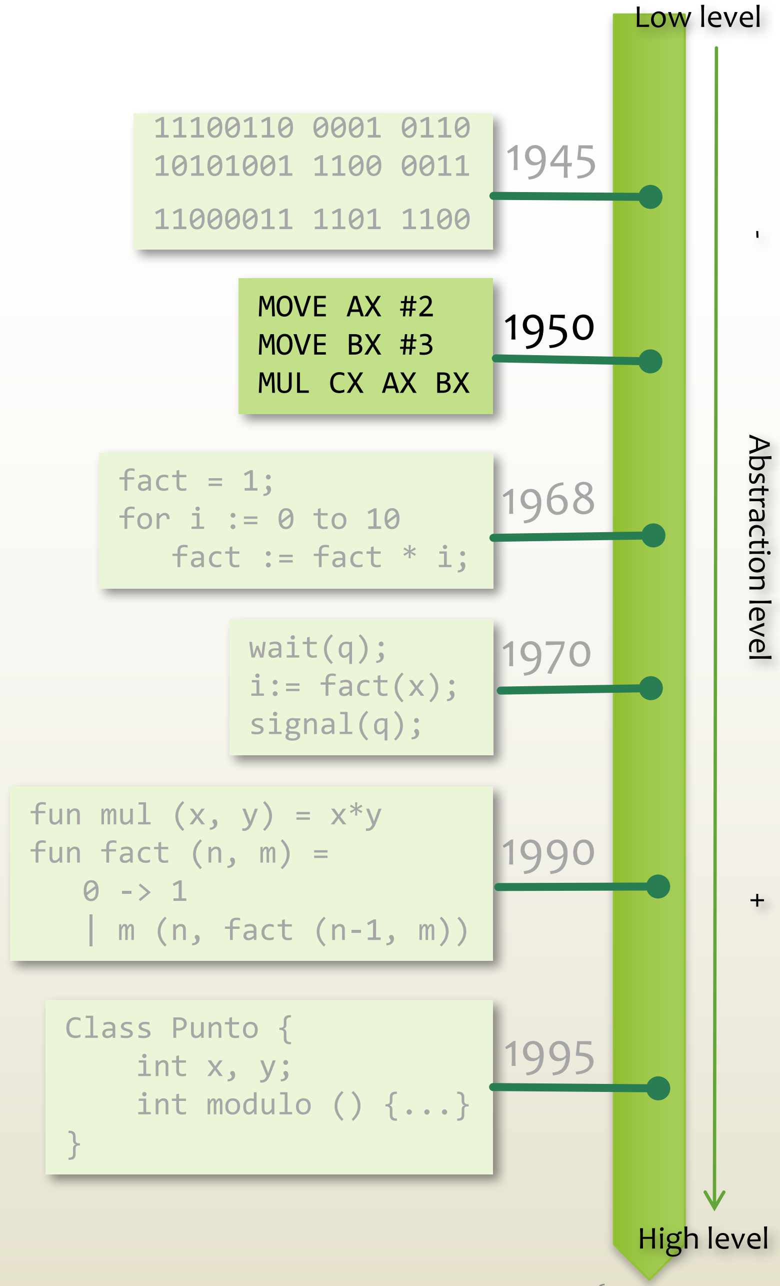
High level

Abstraction effort

Assembler paradigm

- The operation codes are replaced by acronyms
- Operating are replaced by references to memory and records
- The instruction set remains the same

Operation acronym	Operating 1	Operating 2
MOVE	AX	#2
MOVE	BX	[1305]
MUL	CX	AX BX

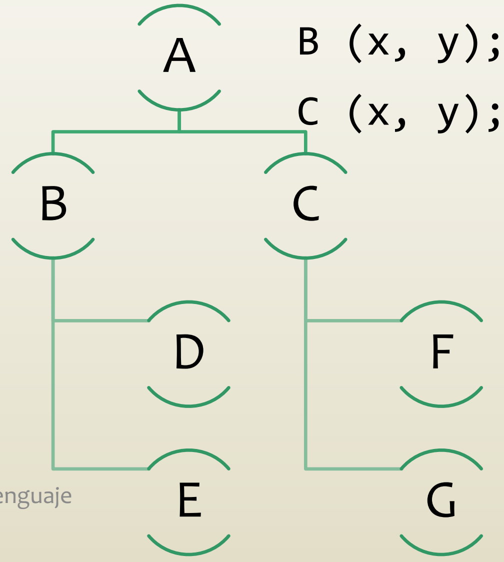


Abstraction effort

Structured imperative paradigm

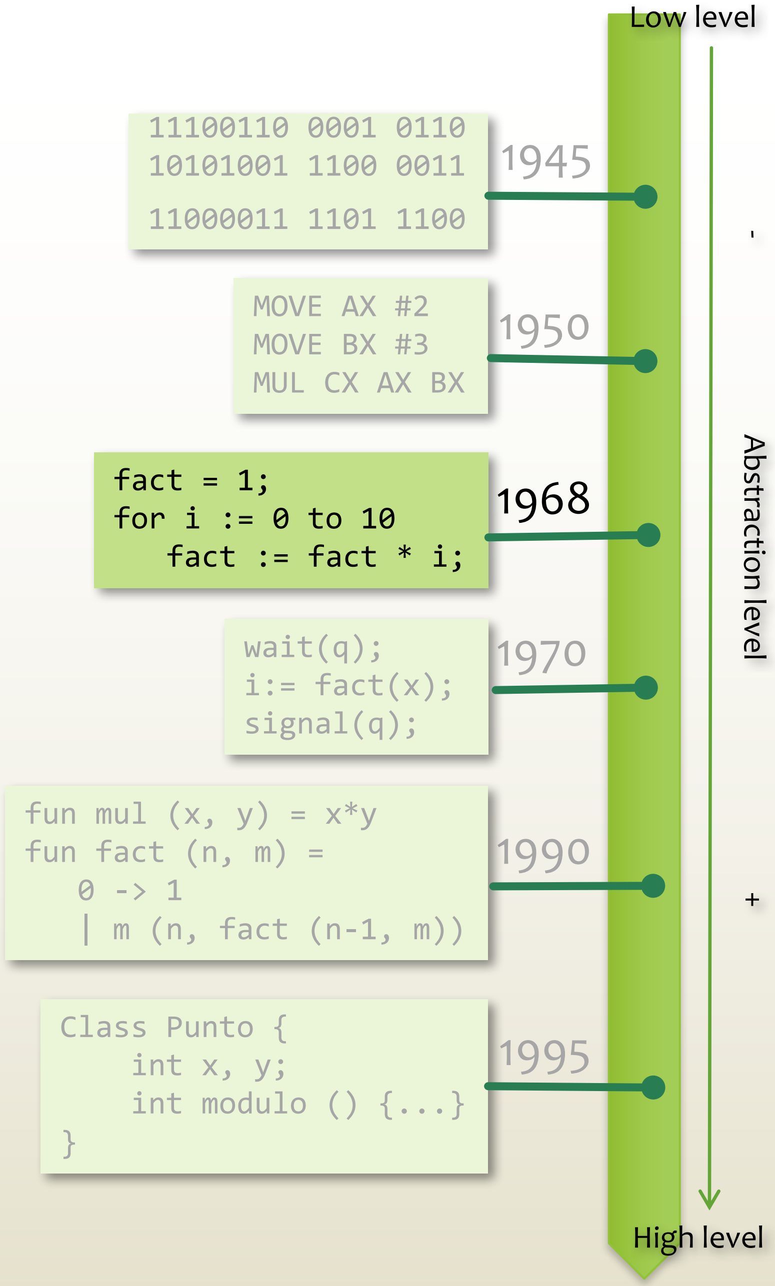
- Sequential execution flow
- Data typification
- Conditional and iterative structures (not jump)
- Subroutines to modularize programs

```
while (x = y)
{
   D (x, y);
   E (x, y);
}
```




```
B (x, y);
C (x, y);
```

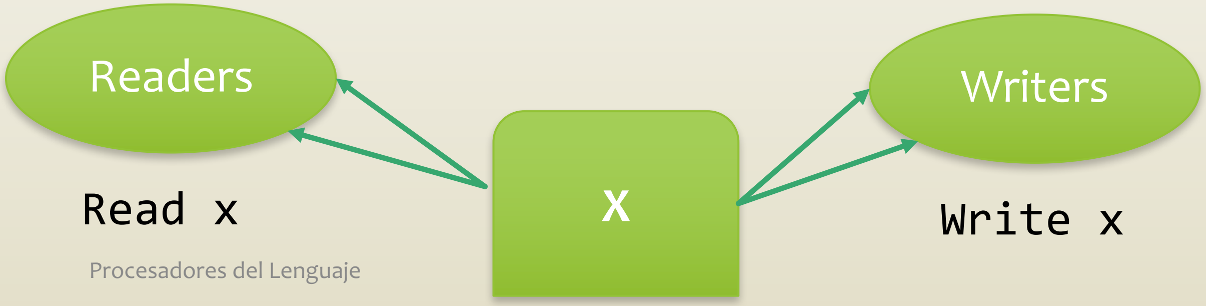
```
if (x > y) F (x);
else G (y);
```

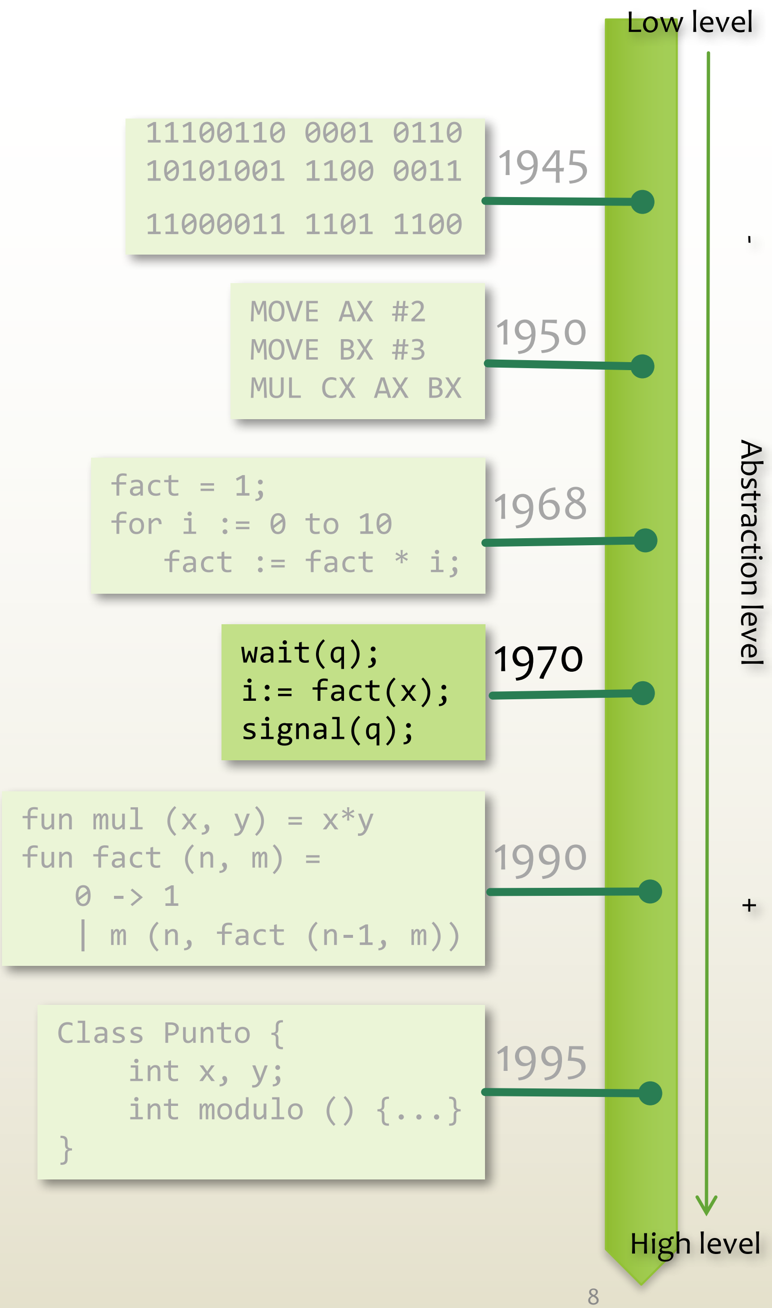


Abstraction effort

Concurrent paradigm

- Several sequential execution flows associated with processes
- Take care concurrent access to resources
- Mechanisms for mutual exclusion and condition synchronization
- The algorithm remains imperative for each process
- There concurrent functional languages



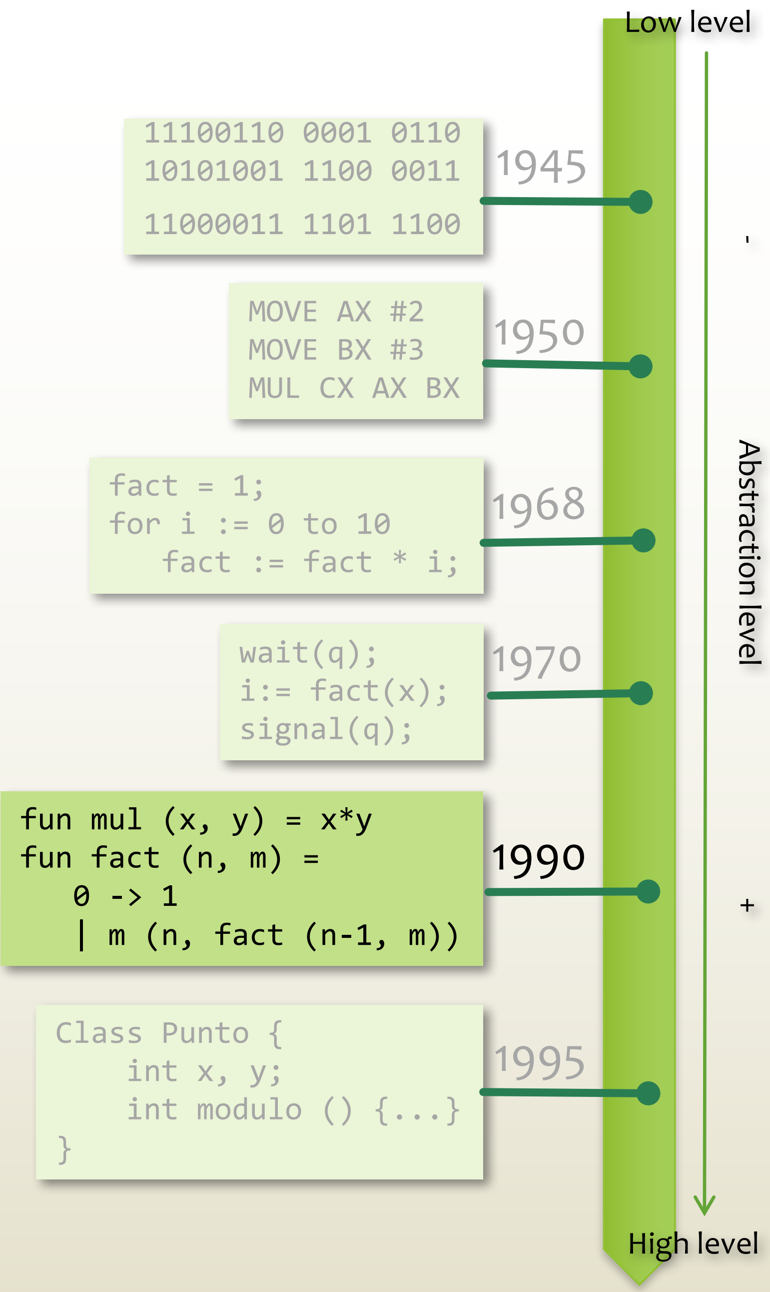


Abstraction effort

Declarative functional paradigm

- Only function declaration
- Expression result depends on its sub-expressions
- No side effects in functional assessment
- No assignment or control structures
- Support is given to the functions recursive definition
- Functions are used like data
- Map / reduce operations

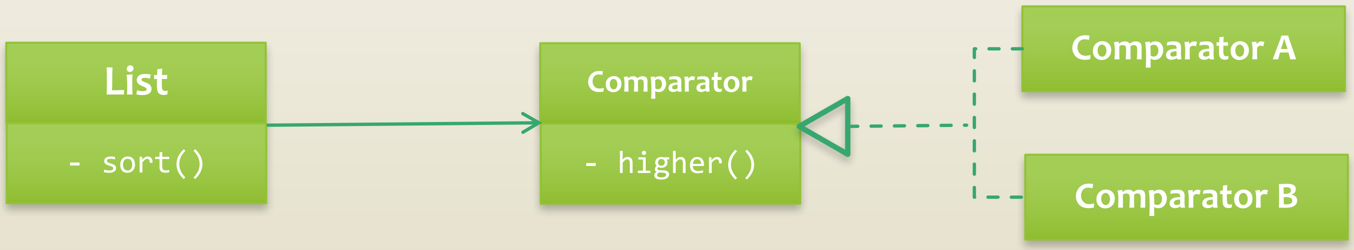
```
fun invertir (l) =
          [] -> []
          | (p: resto) -> invertir(resto): p
```

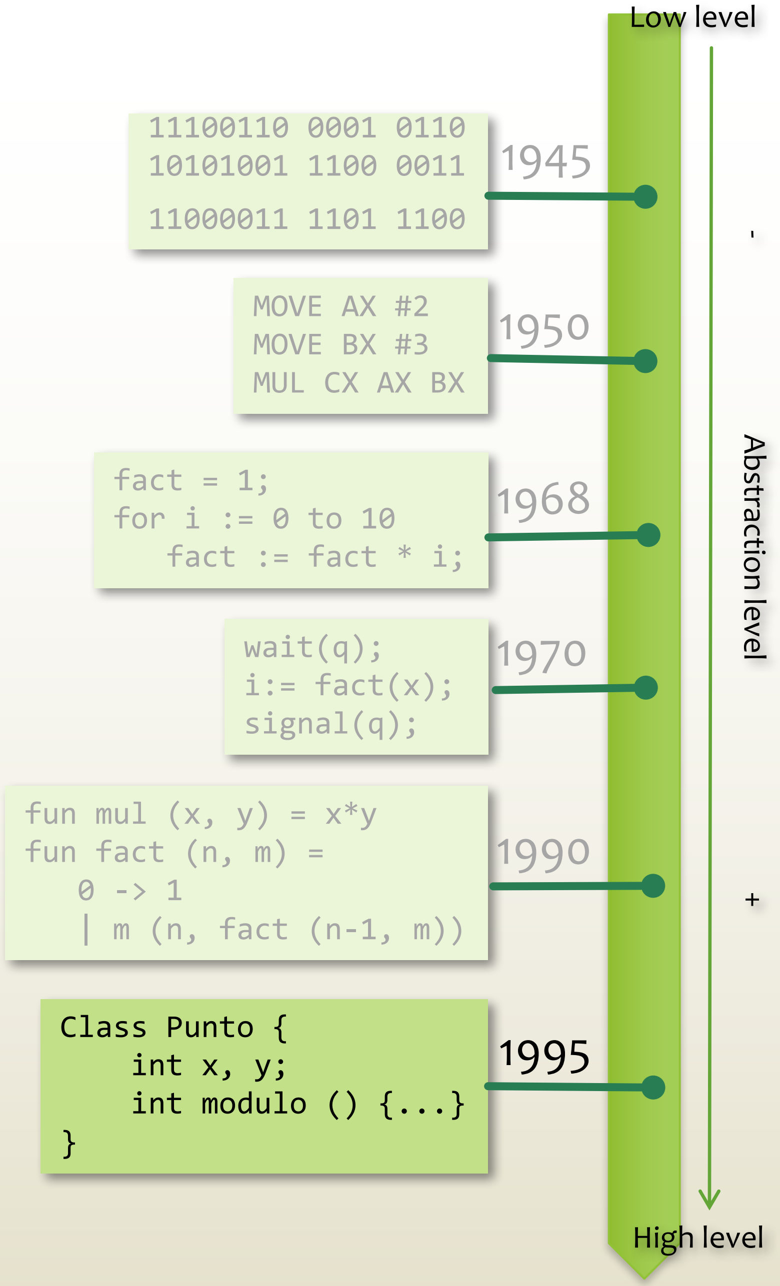


Abstraction effort

Object-oriented paradigm

- Operations accompanying data structures
- Classes with low coupling and strong cohesion
- The algorithm is distributed in the collaboration between objects
- Inheritance, polymorphism, dynamic binding and genericity
- The objects are managed in the heap





Translator / compiler concept and types

Translator concept

- Translator is a software that:
  - Translates a **source program** (program instructions in their original form or programming language)
  - To a **object/machine code** (lower level language)
  - Maintaining the original meaning
- We should distinguish between:
  - Compiler building time
  - Compile time
  - Execution time

Translator / compiler concept

Compiler building time

Our complier source → **Meta - Compiler** → Our executable translator

Compile time

User source program → **Our executable translator** → User object code

Execution time

User data → **User executable program** → Results

Translator types

- According to source and object languages:
  - Assembler (assembler source, object language in machine code)
  - Compiler (source in high level, object language in low level)
  - Translator (from C++ to C, …)
- Incremental translators
- 1 o 2 steps translators
- Translator with optimization
- JIT (Just In Time)
- Etc.

Compilers execution environment

User source program with macros and pseudo instructions

Pre-processor
- User source program without macros

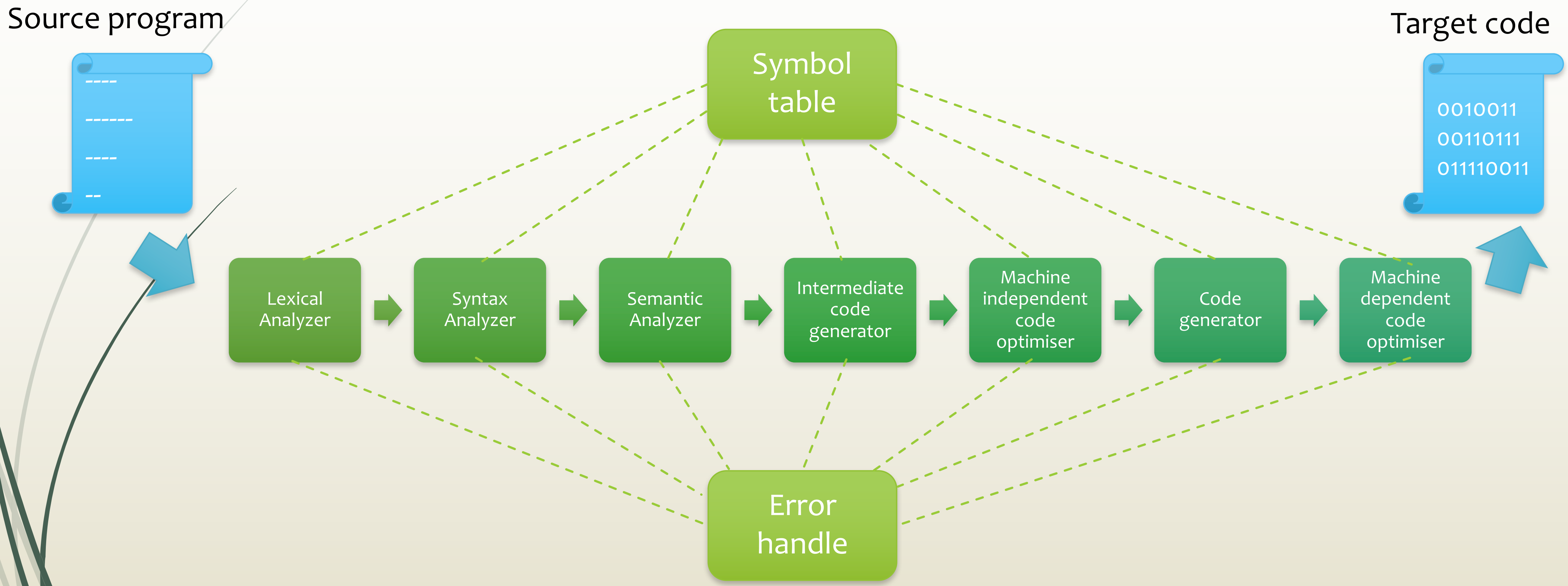
Compiler
- Object program in assembler language

Assembler
- Module in machine code

Linker
- Relocatable program in machine code

Loader
- Executable program

Stages of a compiler



Change in the internal representation: lexical analysis

“energy = total = quantity + 23;” **Character string**

Lexical Analyser

ID$_{energy}$ **ASIGN ID**$_{total}$ **ASIGN ID**$_{cuantity}$ **+ CTEENT**$_{23}$ **;** **Token sequence**

Token	Informal description	Lexeme
CTEENT	Decimal digits sequence. If it starts from zero, it is octal	23, 4356, 03472, 0
ID	Letters and digits sequence starting with a letter	Energy, total, quantity, x, y
ASIGN	The character '='	=
+	The character ‘+'	+

Lexical description

Token	Informal description	Lexeme

CTEENT	Decimal digits sequence. If it starts from zero, it is octal	`digDec [0-9]`
		`digOctal [0-7]`
		
		`{digDec}+|0{digOctal}*`

ID	Letters and digits sequence starting with a letter	`[a-zA-Z_][a-zA-Z0-9_]*`
ASIGN	The character '='	"="
+	The character '+'	"+"

Syntax description (grammar, BNF)

- `ExprAsign -> ID ASIGN ExprAsign`
- `ExprAsign -> ExprAritmetica`
- `ExprAritmetica -> ExprAritmetica + ExprAritmetica`
- `ExprAritmetica -> ExprAritmetica – ExprAritmetica`
- `ExprAritmetica -> ID`
- `ExprAritmetica -> CTEENT`

These rules are independent of the lexemes value!!

Change in the internal representation: Syntax analysis

IDenergy ASIGN IDtotal ASIGN IDcuantity + CTEENT23 ;

Token sequence

Syntax Analyzer

Analysis tree(or concrete syntax tree)

It represents the steps the analyser (theorem prover) to discover the structure of input from your grammar

Symbol table

energy	....
total	....
quantity	....

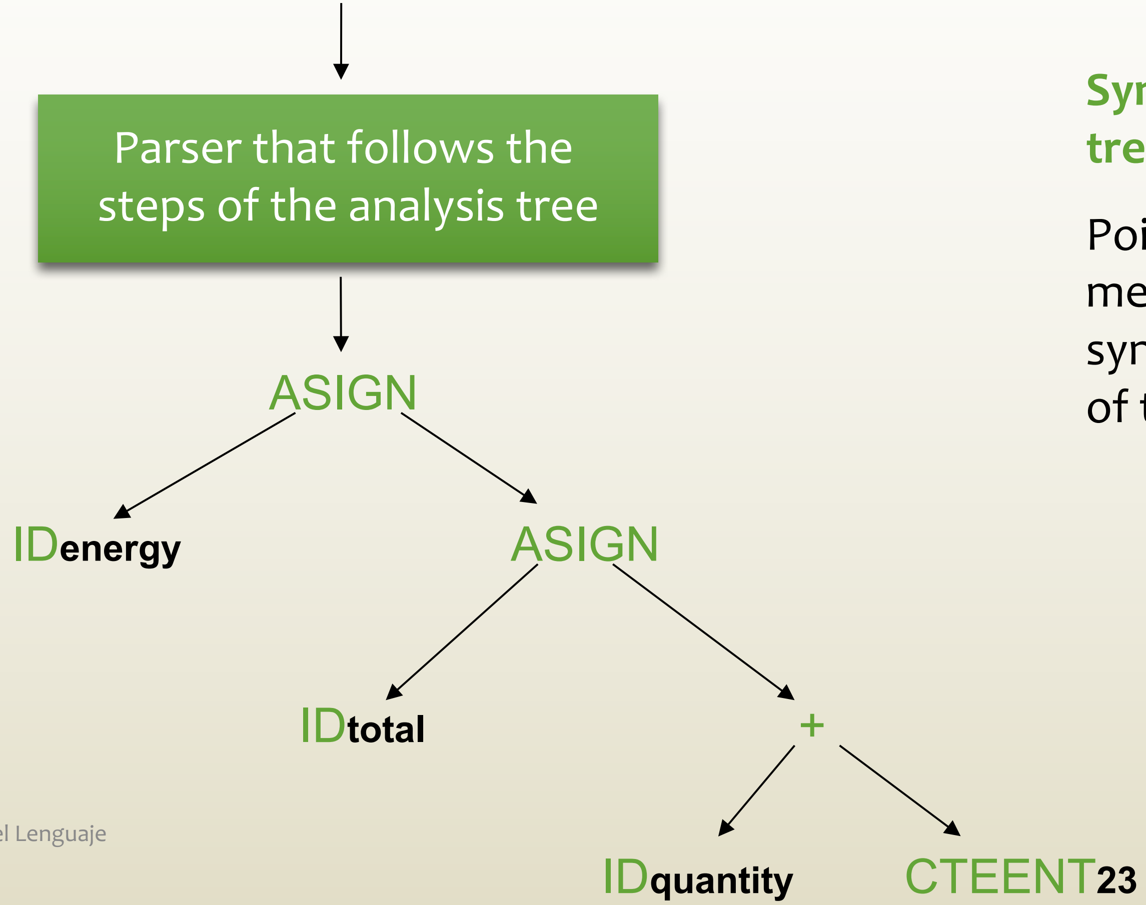
Steps during de parsing: Ascending and descending parsing

```
ExprAsign -> ID ASIGN ExprAsign
ExprAsign -> ExprAritmetica
ExprAritmetica -> ExprAritmetica + ExprAritmetica
ExprAritmetica -> ExprAritmetica - ExprAritmetica
ExprAritmetica -> ID
ExprAritmetica -> CTEENT
```

Change in the internal representation: first intermediate code

ID_{energy} **ASIGN** ID_{total} **ASIGN** $\mathrm{ID}_{cuantity}$ **+** CTEENT_{23} **;**

Token sequence



Symbols table

energy	….
total	….
quantity	….

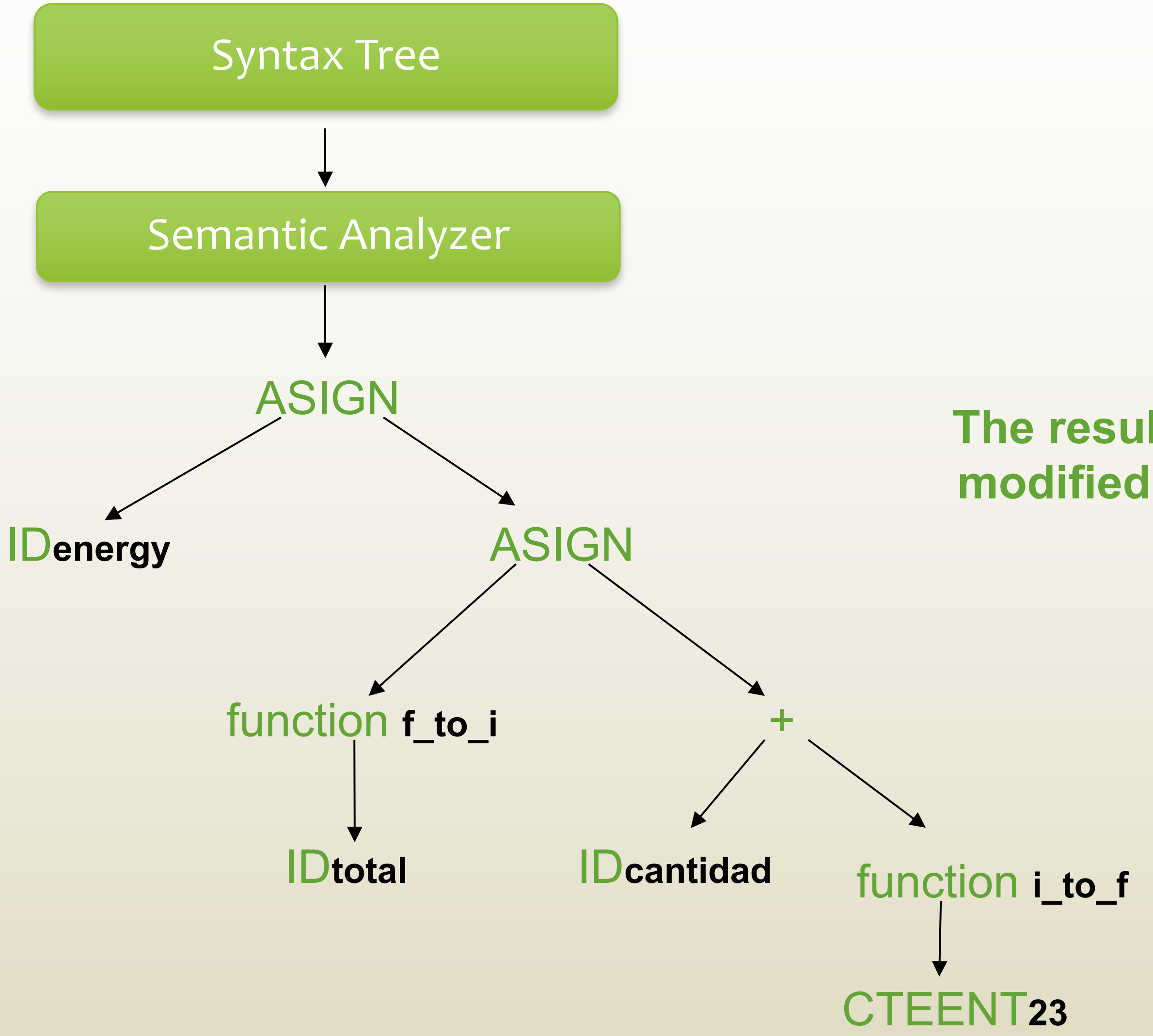
Syntax tree (or abstract syntax tree)

Pointers made structure in memory that represents the syntactic structure without details of the analysis method used

Change in the internal representation: Semantic analysis (Or contextual constraints)

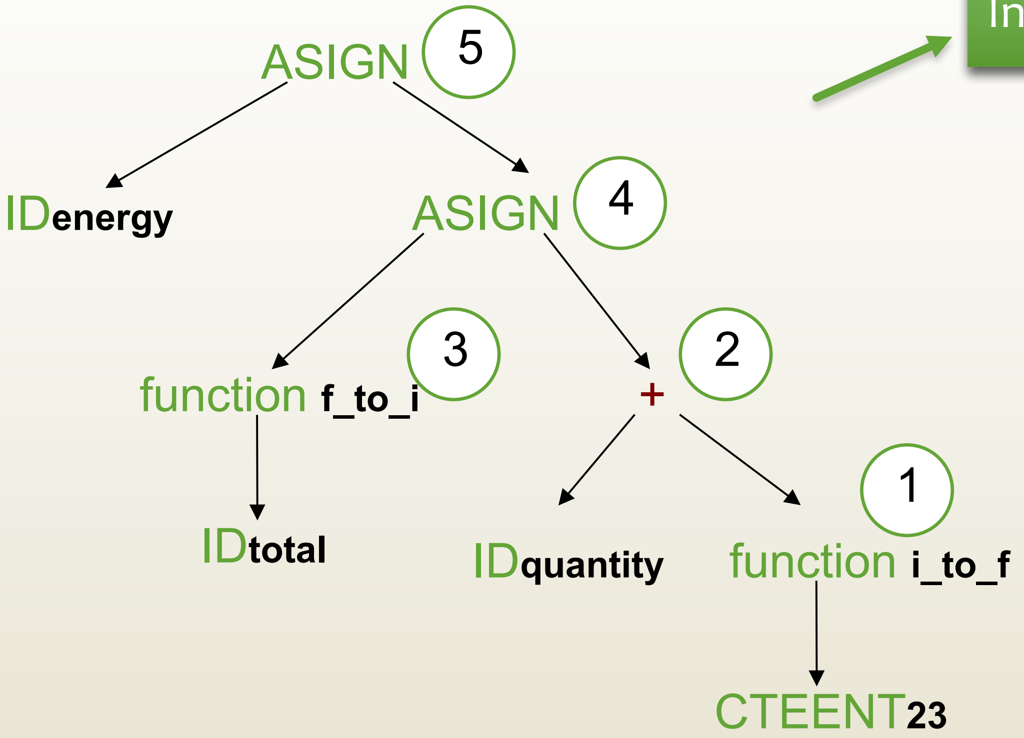
Symbols table

energy	Float
total	Integer
quantity	Float



The result is another modified syntax tree

Intermediate code generator: 3-way code



Intermediate code generator

```
Temp1 = i_to_f(23)
Temp2 = quantity + Temp1
Temp4 = Temp2
Temp3 = f_to_i(Temp4)
total = Temp3
Temp5 = Temp4
energy = Temp5
```

Intermediate code optimizer

- Constant propagation
- Copy propagation
- Algebraic simplifications
- Common subexpression elimination
- Etc.

```
Temp1 = i_to_f(23)
Temp2 = quantity + Temp1
Temp4 = Temp2
Temp3 = f_to_i(Temp4)
total = Temp3
Temp5 = Temp4
energy = Temp5
```

Intermediate code optimizer

```
Temp2 = quantity + 23.0
total = f_to_i(Temp2)
energy = Temp2
```

Temp2 = cantidad + 23.0

total = f_to_i(Temp2)

energia = Temp2

Code generator

```
.file       "p.c"
.section    .rodata
.LC0:
.long       1102577664     # almacenamiento estatico para constante 23.0

.text
.globl main
.type       main, @function
main:
. . .
flds        cantidad                # variable "cantidad" a la pila
flds        .LC0                    # constante "23.0" a la pila
faddp       %st, %st(1)             # Sumar los elementos de la pila
fstps       -8(%ebp)                # almacenar el resultado en memoria (T2)


flds        -8(%ebp)                # Temporal (T2) a la pila
fnstcw      -22(%ebp)               # salvar palabra control FPU en memoria
movzwl      -22(%ebp), %eax
movb        $12, %ah                # modificar el redondeo por abajo
movw        %ax, -24(%ebp)          # volver a cambiar la palabra de control de FPU
fldcw       -24(%ebp)
fistpl      -28(%ebp)               # convertir a %st(0) a entero y almacenarlo
fldcw       -22(%ebp)               # restaurar la palabra de control de FPU
movl        -28(%ebp), %eax
movl        %eax, total             # almacenar resultado en variable "total"

movl        -8(%ebp), %eax          # Temporal (T2) al registro acumulador
movl        %eax, energia           # acumulador a la variable "energia"
. . .

.comm       cantidad,4,4            # almacenamiento estático para las variables
.comm       energia,4,4
.comm       total,4,4
```

Other phases

Symbol table management

- During the other phases.

Error detection and error messages issues

Grouping the analysis and synthesis phases

- Sometimes phases of lexical, syntactic and semantic analysis are brought together to form the front end(depending on the source language).
- The generation and optimization phases are joined to form the back end (language dependent object).