Part I. Introduction to Compilers

Compiler

- **Input:** Source program
- **Output:** Target program

- **Method:**
- A compiler reads a *source program* (in source language) and translates them into *target program* (in target language).
- Source and target programs are *functionally equivalent*.

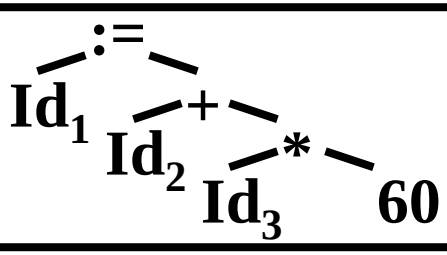
Structure of Compiler: Phases

```
Position := Initial + Rate * 60
```

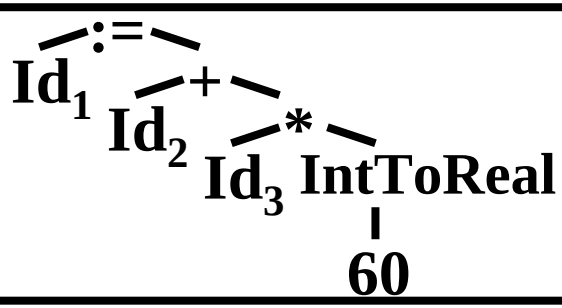
Lexical analyzer

$Id_1 := Id_2 + Id_3 * 60$

Syntax analyzer



Semantic analyzer



Intermediate code generator

```
T1  := IntToReal(60)
T2  := Id3 * T1
T3  := Id2 + T2
Id1 := T3
```

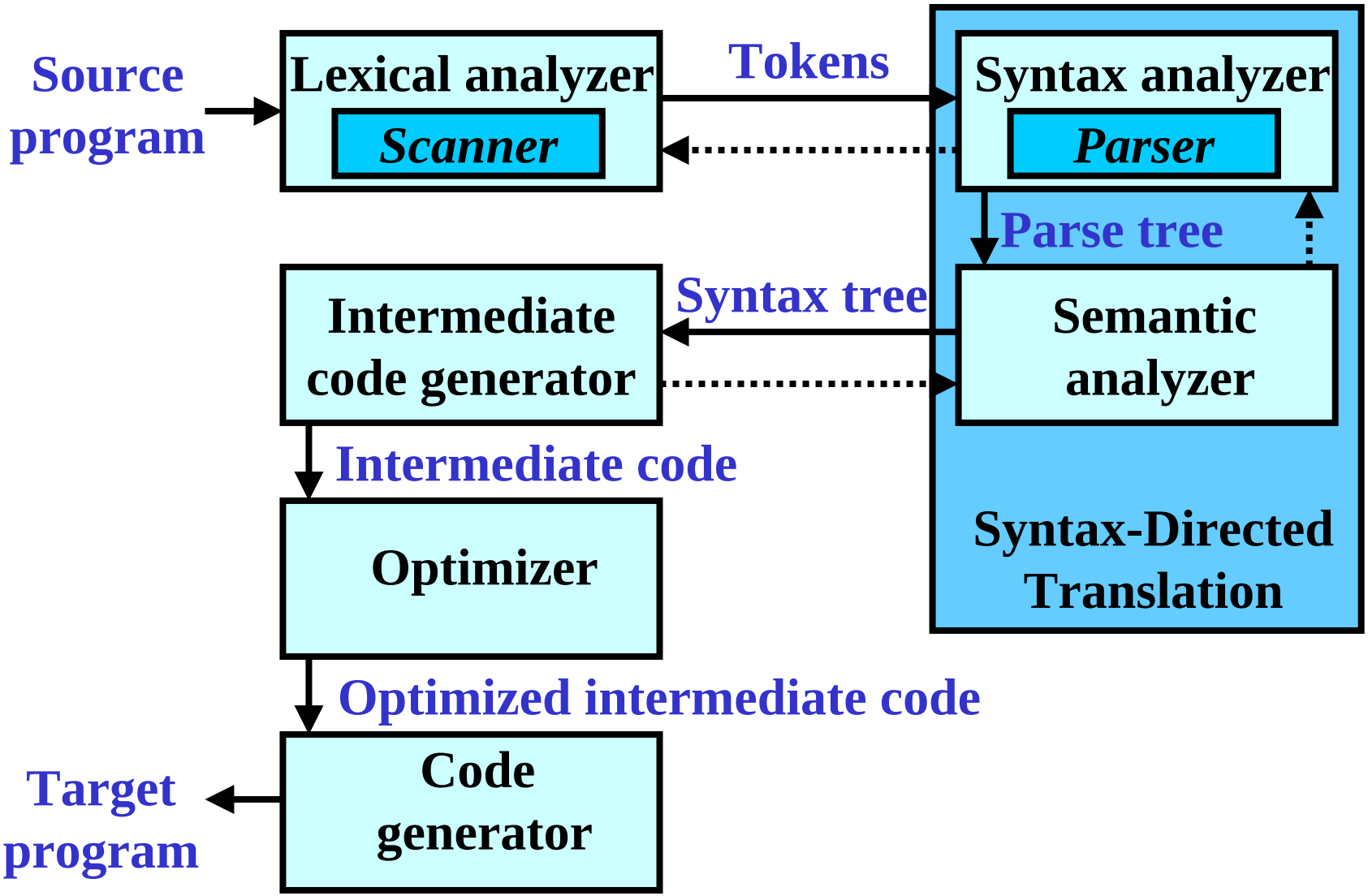
Optimizer

```
T1  := Id3 * 60.0
Id1 := Id2 + T1
```

Code generator

```
fmov R2 , Id3
fmul R2 , #60.0
fmov R3 , Id2
fadd R2 , R3
fmov Id1, R2
```

Structure of Compiler: Construction



Languages and Compilers

Theoretical view.

Σ = {***a***, ***b***}, $L = \{a^n b^n : n \geq 0\}$

Question: ***aabb*** $\in L$ **?**

Practical view.

Σ = {***begin***, ***end***, ***id***, **:=**, *****, **;** , **...**},

L_{Pascal} = Programming Language Pascal

Question: ***begin id*** **:=** ***id*** ***** ***id*****;** ***end*****;** $\in L_{Pascal}$ **?**

YES: Program is **OK** ⇒ Create a target program

NO: Program is **not OK** ⇒ Handle the errors

Lexical analyzer (Scanner)

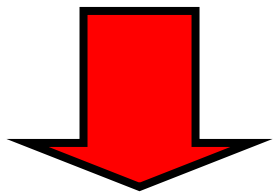
- **Input:** Source program
- **Output:** String of tokens

- **Method:**
- Source program is broken into *lexemes* = logically cohesive lexical entities – (identifiers, numbers, key-words, operators,...)
- Lexemes are represented by uniform *tokens*
- Some tokens have *attributes*

Lexical analyzer: Example

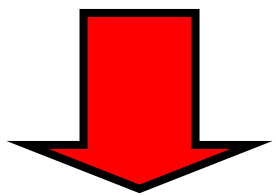
Source program:

```
Position := Initial + Rate * 60
```



Lexemes:

Position	:=	Initial	+	Rate	*	60



Tokens:

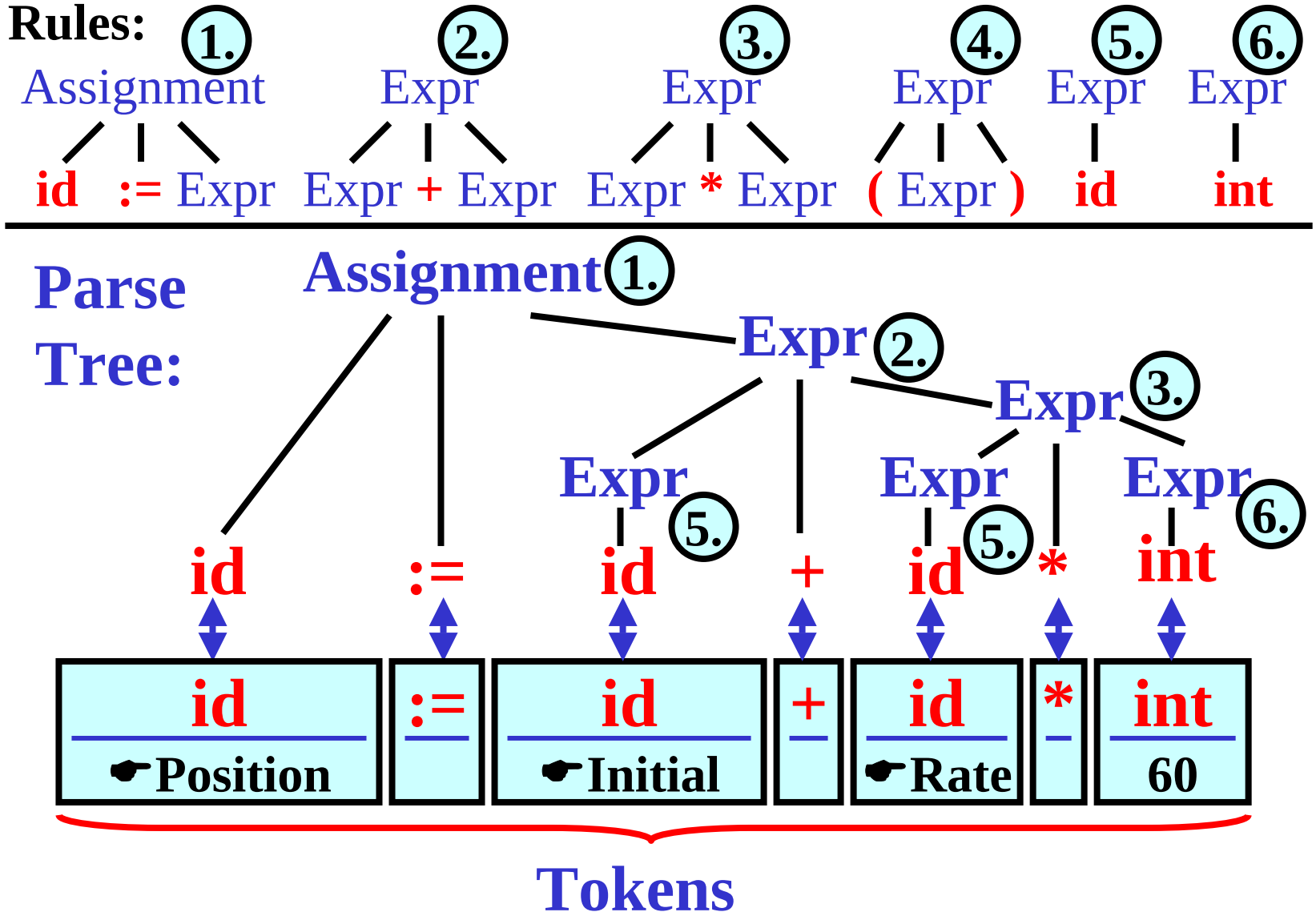
id	:=	id	+	id	*	int
☛Position		☛Initial		☛Rate		60

Syntax analyzer (Parser)

- **Input:** String of tokens
- **Output:** Parse tree

- **Method:**
- Parser verifies that the string of tokens represents a syntactically well-formed program
- If it finds a *parse tree* for the string, it is correct; otherwise, it is not
- Construction of tree is based on grammatical rules
- Two approach: top-down and bottom-up

Syntax analyzer: Example



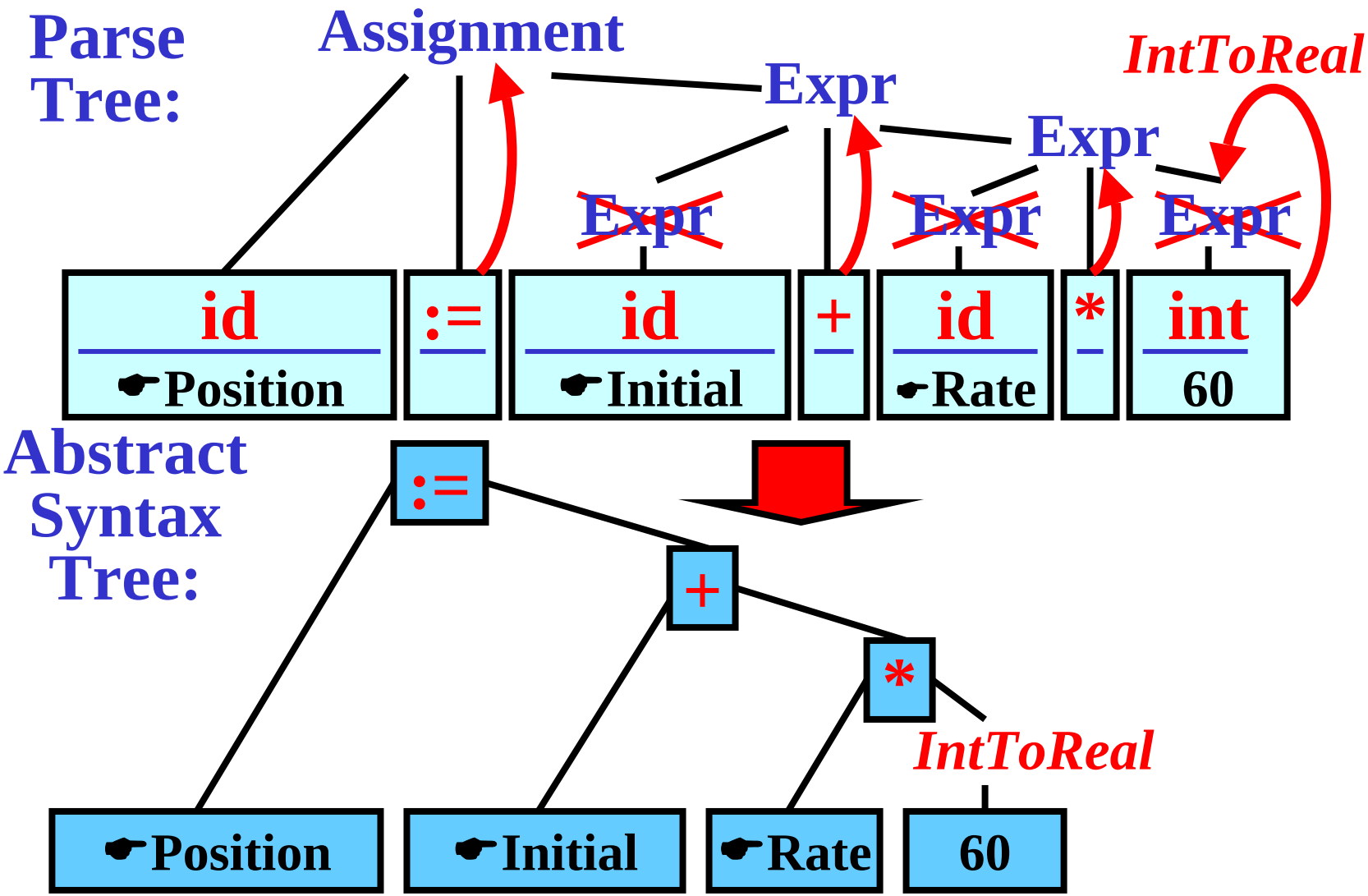
Semantic analyzer

- **Input:** Parse tree
- **Output:** Abstract syntax tree

- **Method:**
- Semantic analyzer checks semantic aspects:
  - *type checking*, which may imply conversions (for example int-to-real)
  - *checking declaration of variables*
- **Syntax-Directed Translation:**

  Parser controls:
  - Semantic actions
  - Generation of syntax tree

Syntax-Directed Translation: Example



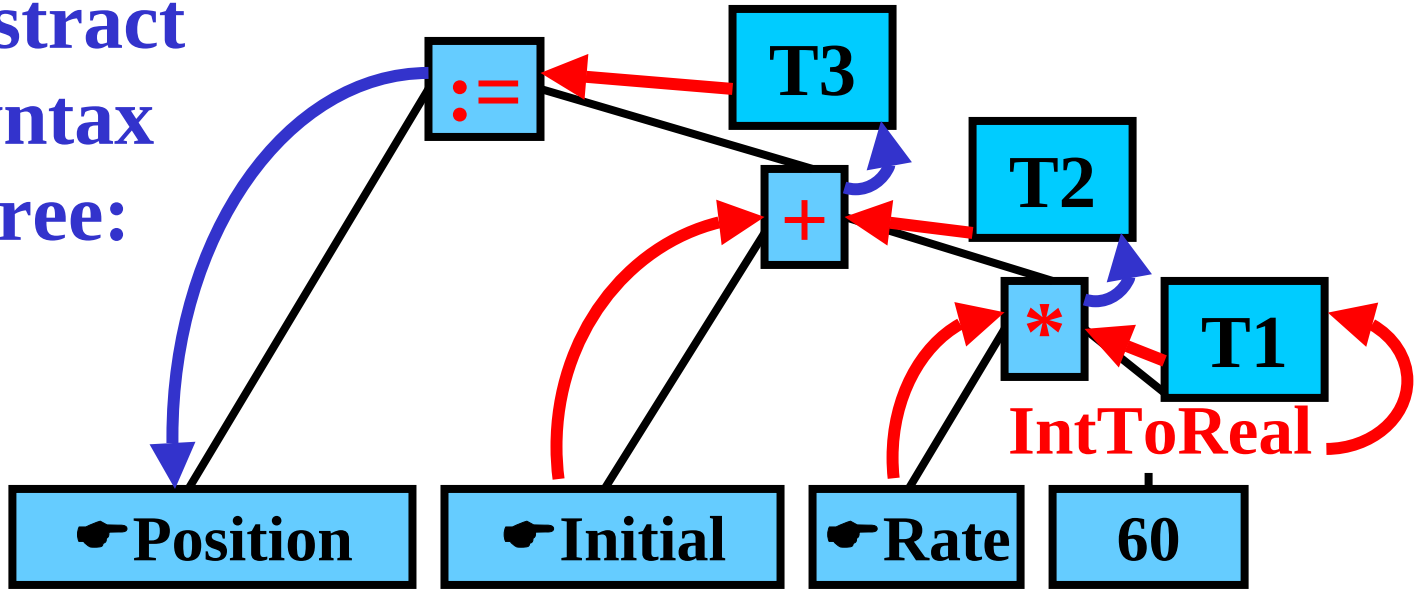
Intermediate code generator

- **Input:** Abstract syntax tree
- **Output:** Intermediate code

- **Method:**
- Intermediate code generator produces the internal version of target program called *intermediate code* for these reasons:
  - uniformity
  - direct translation to target program is difficult and “rough”
  - optimization

Intermediate code generator: Example

Abstract Syntax Tree:



Intermediate code:

```
T1 := IntToReal(60)
T2 := ^Rate * T1
T3 := ^Initial + T2
^Positon := T3
```

Optimizer

- **Input:** Intermediate code
- **Output:** Optimized intermediate code

- **Method:**
- Optimizer makes more efficient version of intermediate code called *optimized intermediate code*:
  - **Constant propagation:** (a := 1; b := 2; c := a + b ⇒ c := 3)
    Note: *Variables a, b have no next use*
  - **Copy propagation:** (b := a; c := b; d := c ⇒ d := a)
    Note: *Variables b, c have no next use*
  - **Dead code elimination:** (**while** false **do …** ⇒ nothing)

⋮

Note: Some compilers have no optimizer

Optimizer: Example

Intermediate code:

```
T1 := IntToReal(60)
T2 := ↙Rate * T1
T3 := ↙Initial + T2
↙Positon:= T3
```

Optimized intermediate code:

```
T2 := ↙Rate * 60.0
↙Positon := ↙Initial+T2
```

Code Generator

- **Input:** Optimized intermediate code
- **Output:** Target program

- **Method:**
- Optimized intermediate code is converted to *target program*
- Target program is written in target language
- In reality, target language is assembly or machine language

Code Generator: Example

Optimized intermediate code:

```
T2 := ↼Rate * 60.0
↼Positon := ↼Initial+T2
```

Target program:

```
fmov R2, ↼Rate
fmul R2, #60.0
fmov R3, ↼Initial
fadd R2, R3
fmov ↼Position,R2
```

R2 ≅ T2