Foundations of Programming Languages

Overview: Compilers

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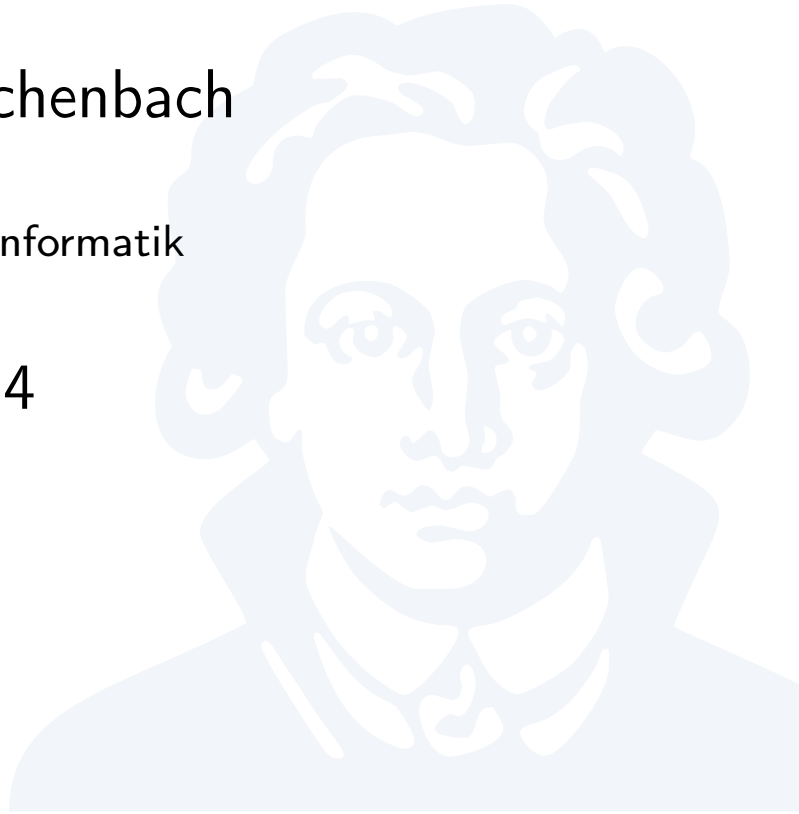
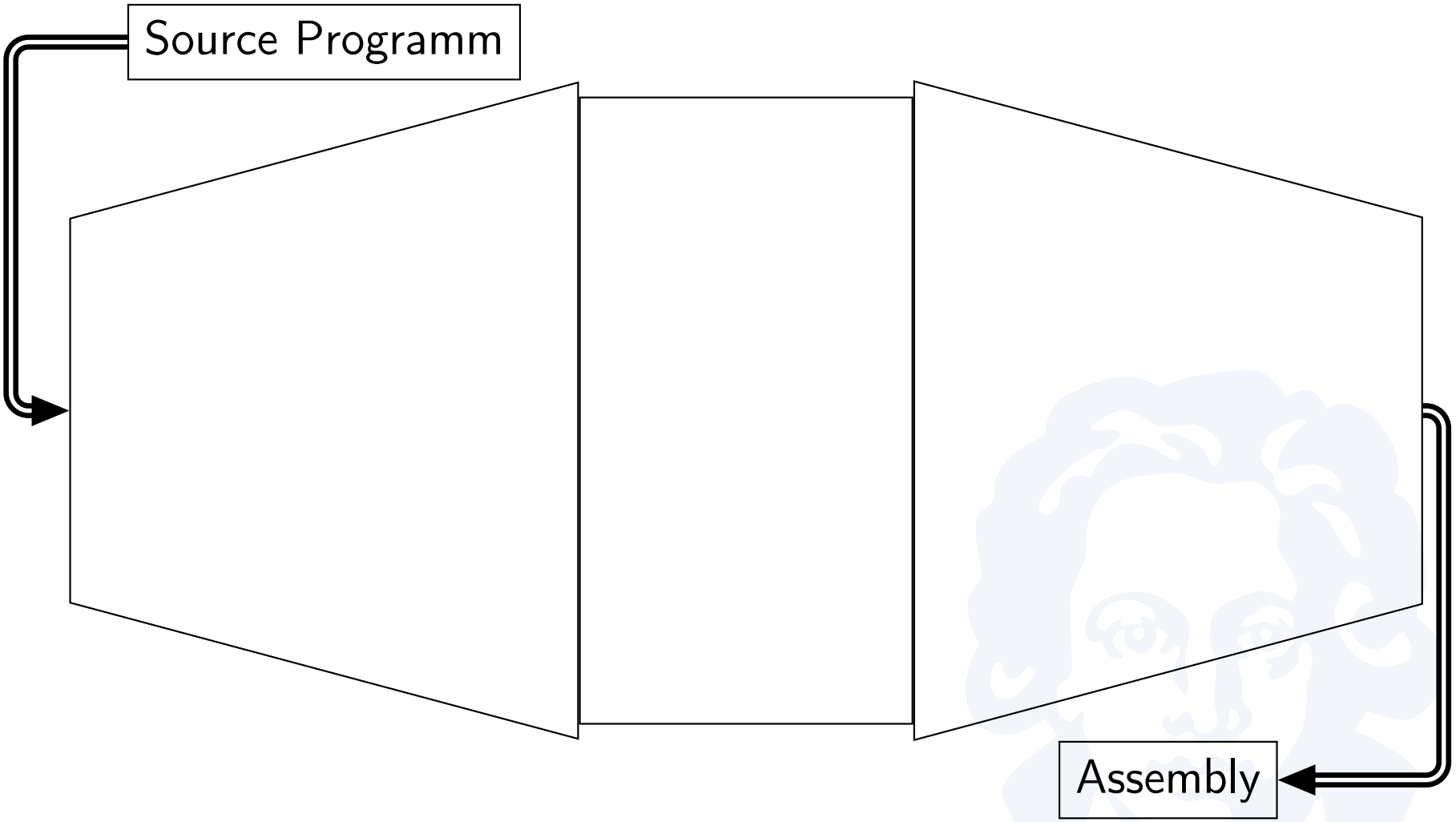


Compilers



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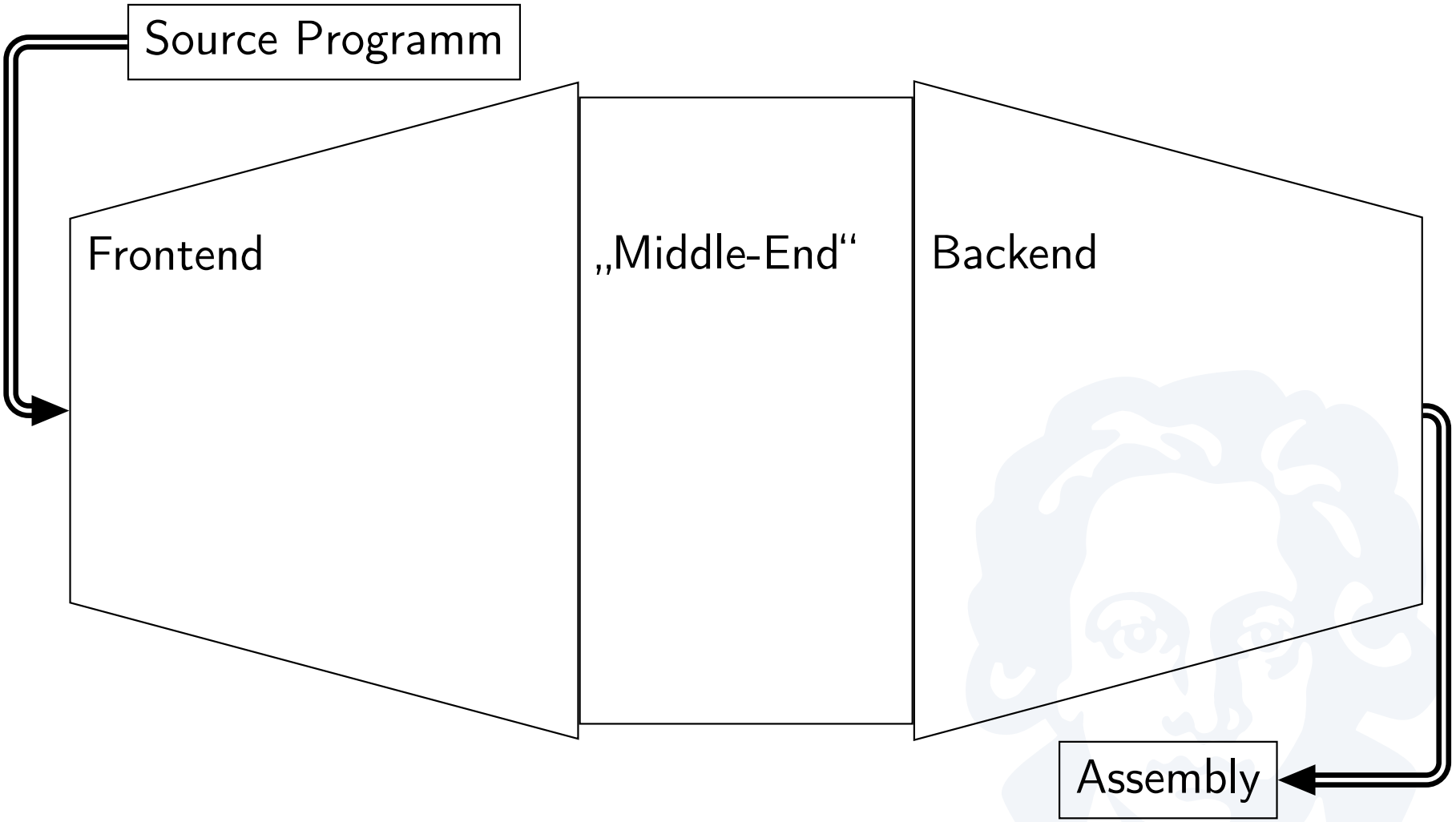

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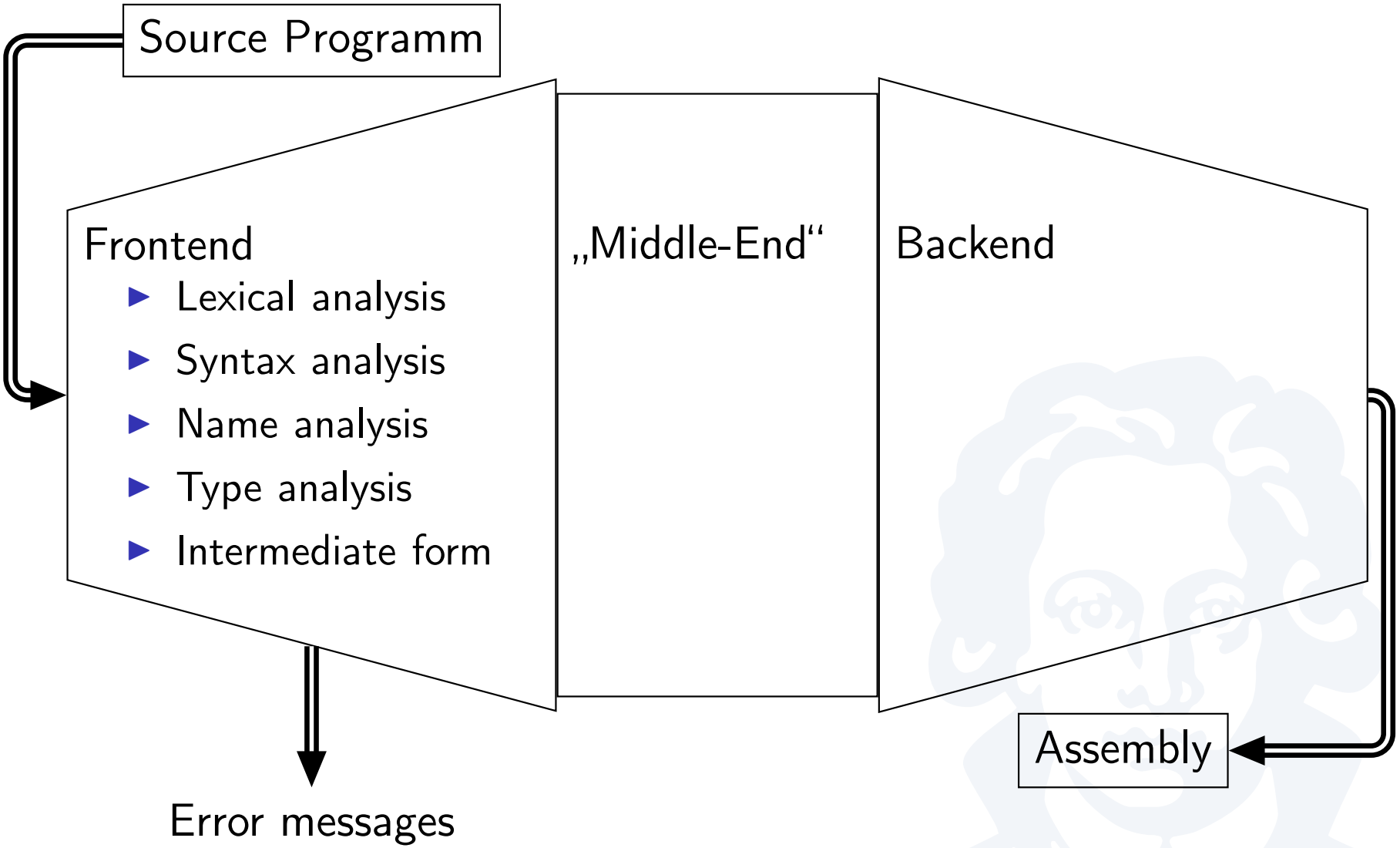
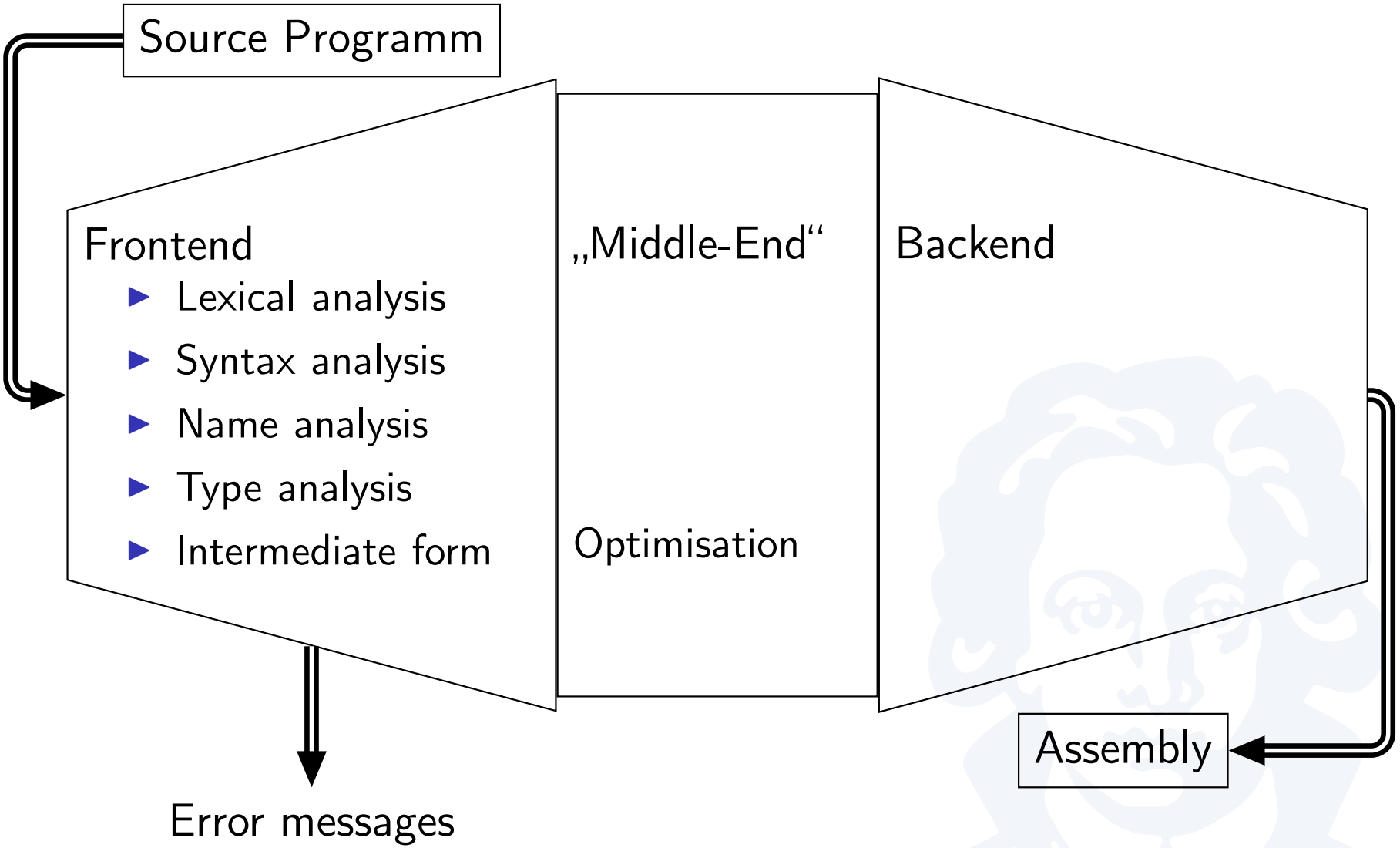

Source Programm
Frontend
Lexical analysis
Syntax analysis
Name analysis
Type analysis
Intermediate form
„Middle-End“
Backend
Assembly
Error messages

Compilers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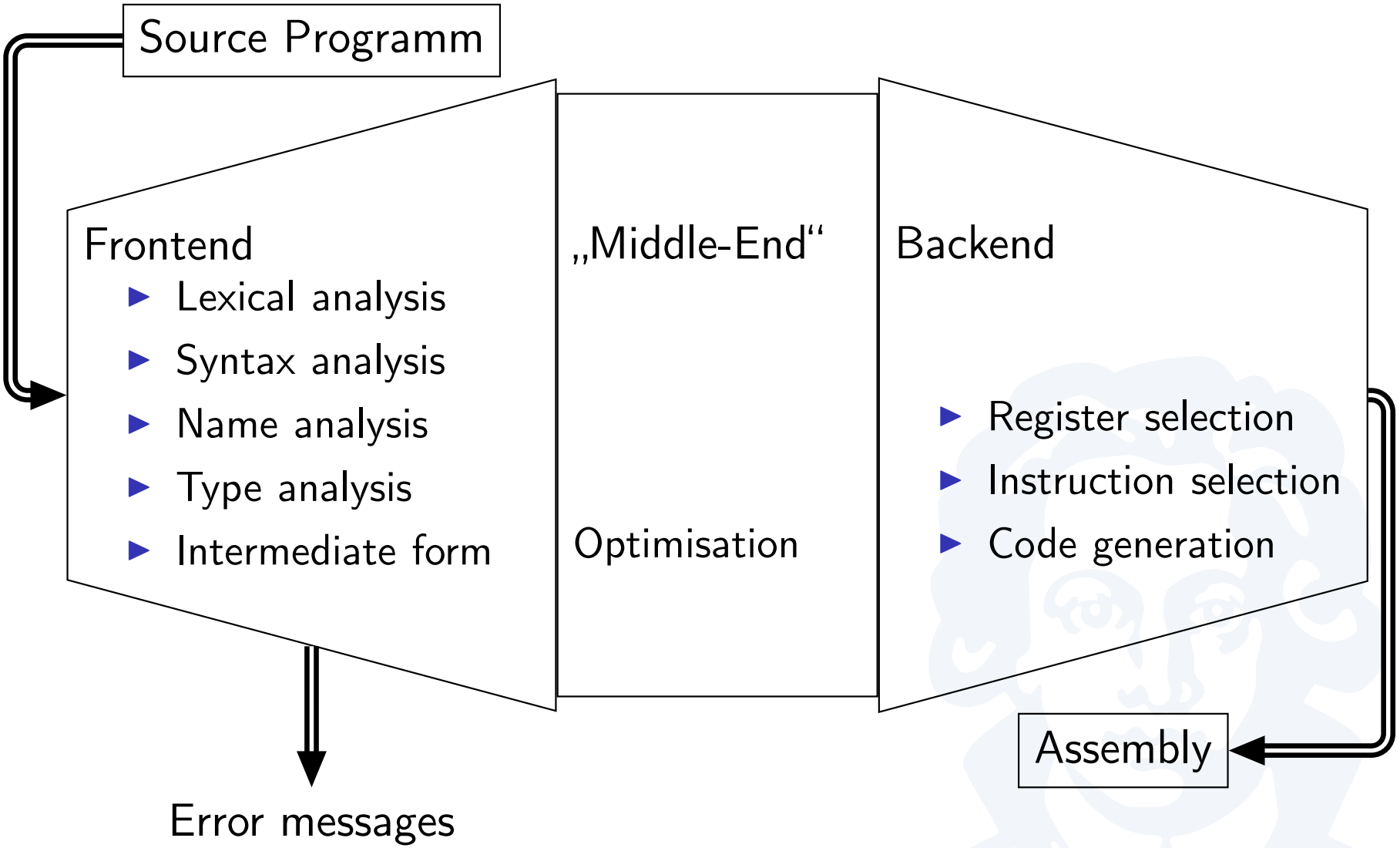
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Register selection
Instruction selection
Code generation
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Java lexing

```
int i;
if (2 > 0) {
  i = "One";
}
return i;
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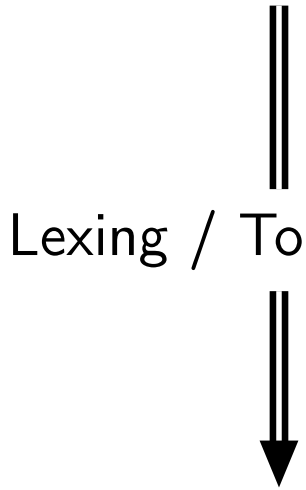
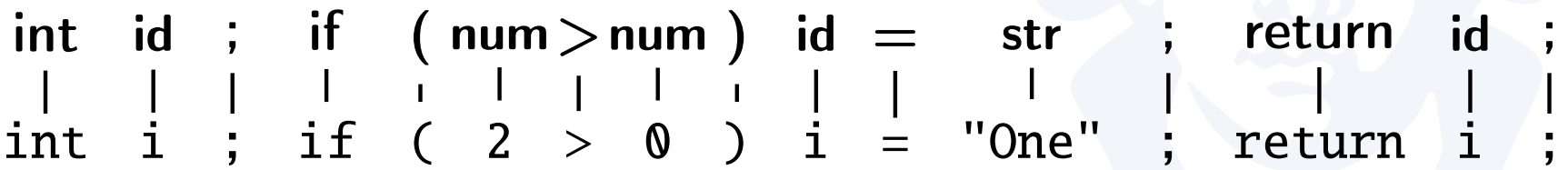


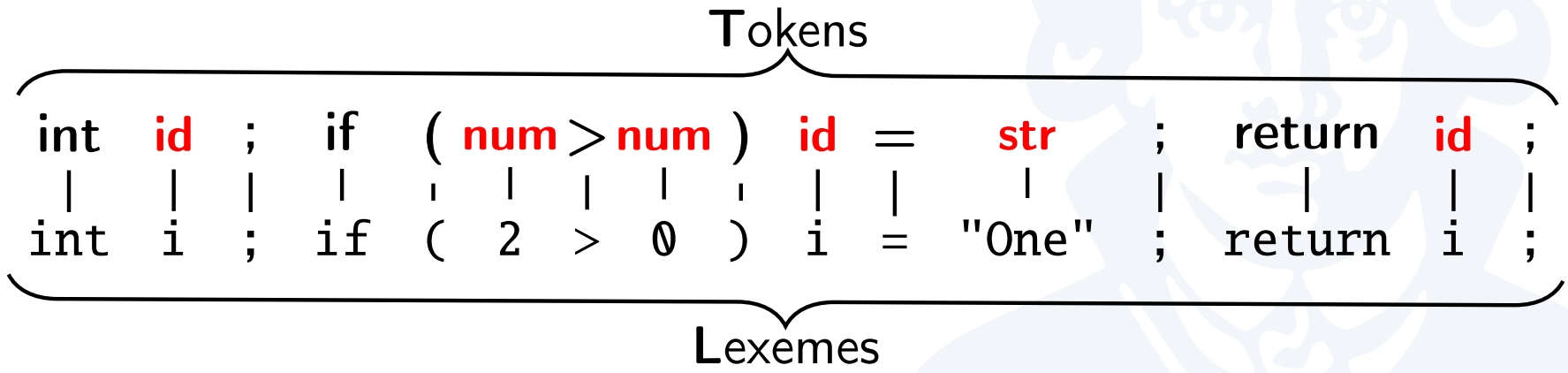
Lexing / Tokenisation


```
int  i  ;  if  (  2  >  0  )  i  =  "One"  ;  return  i  ;
```

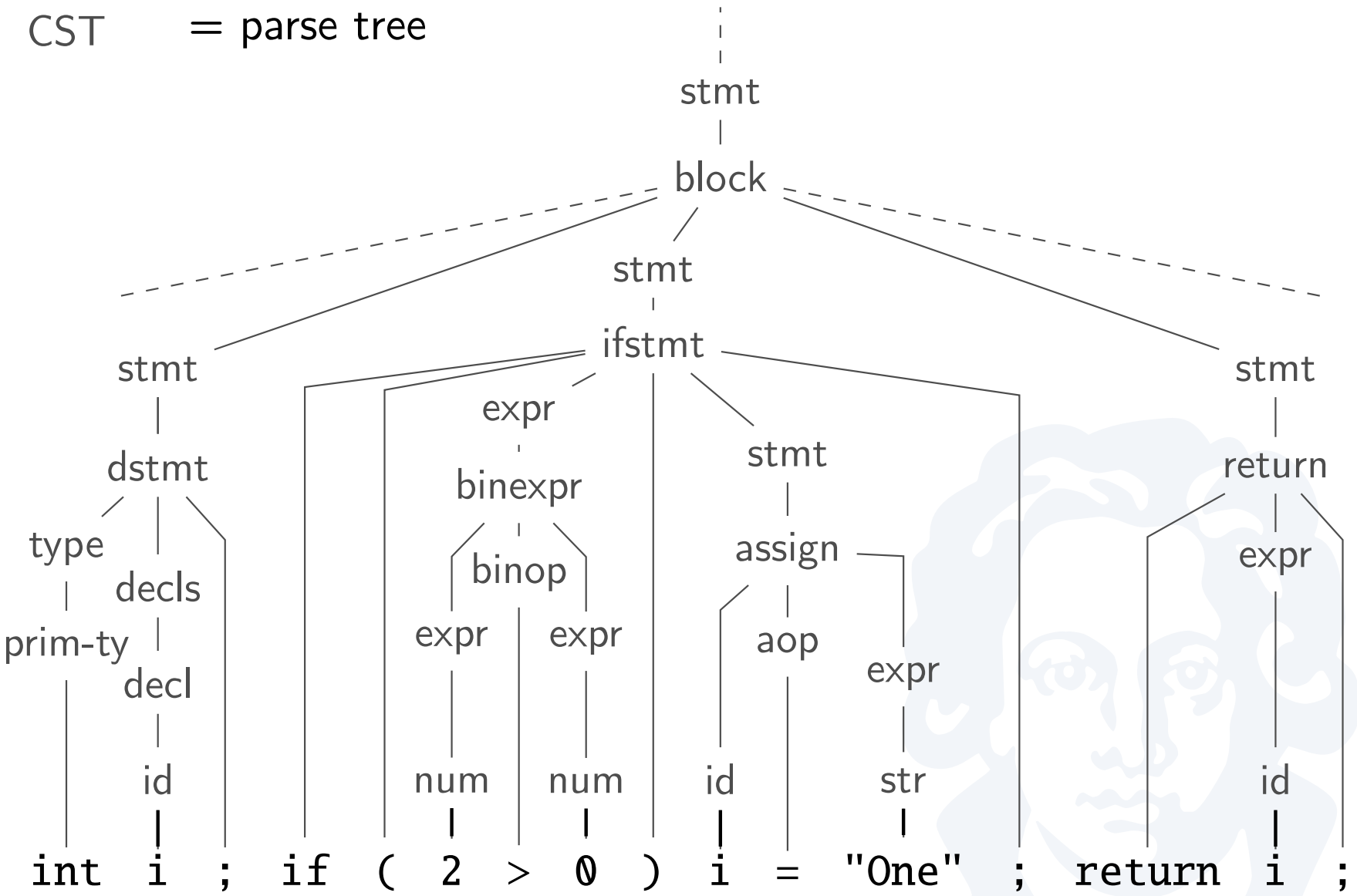
Java lexing & parsing



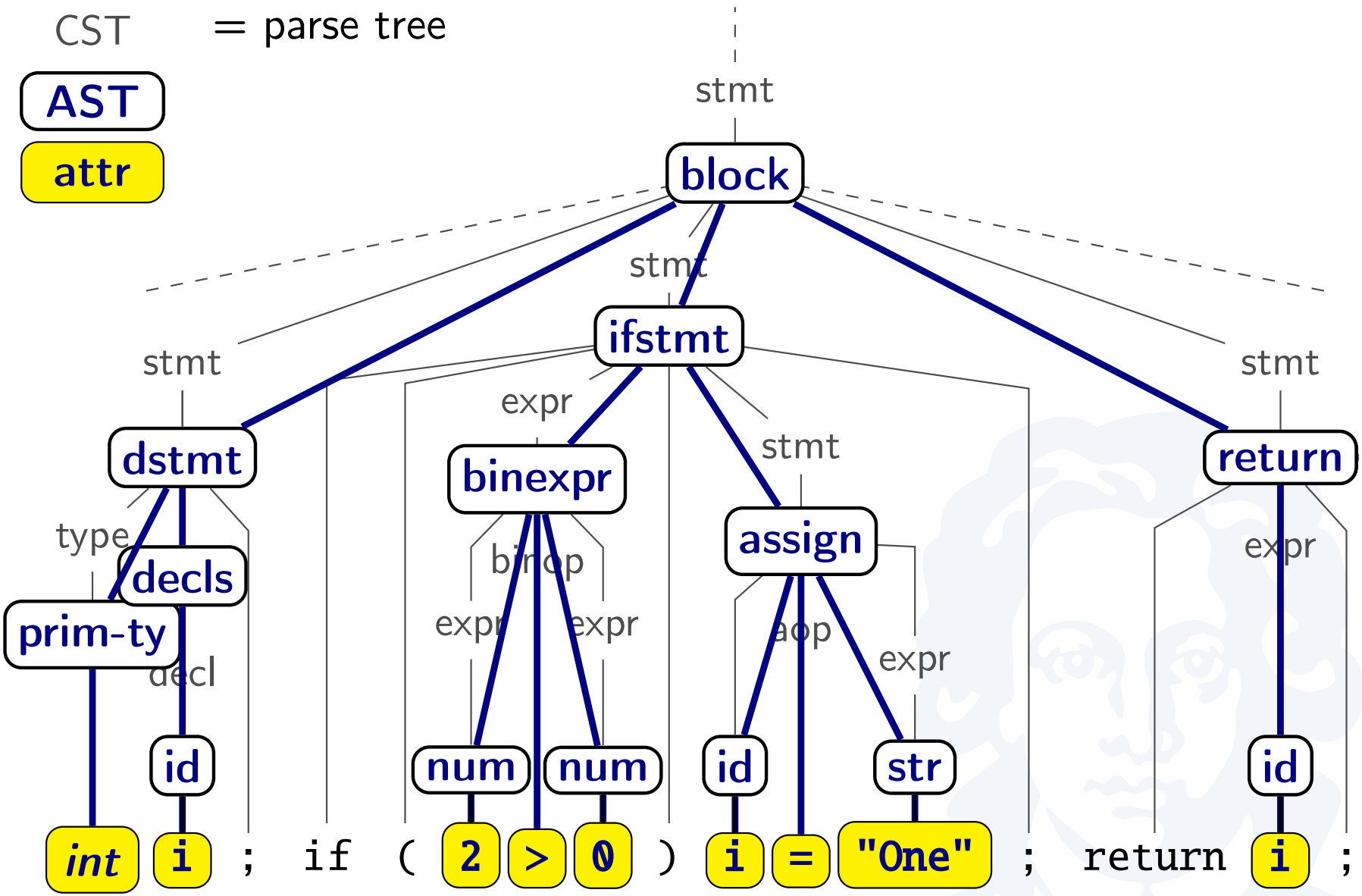
Java lexing & parsing



Java lexing & parsing



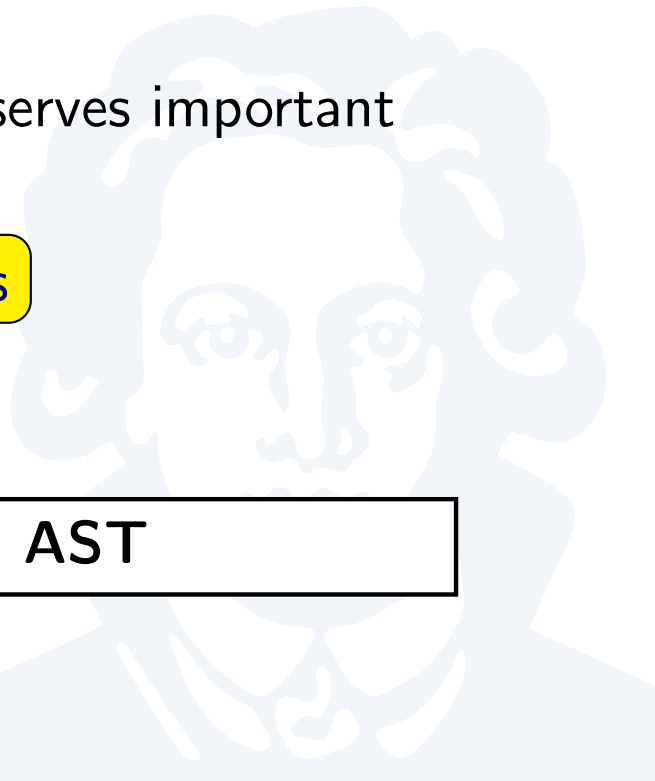
Java lexing & parsing



Parsing in general

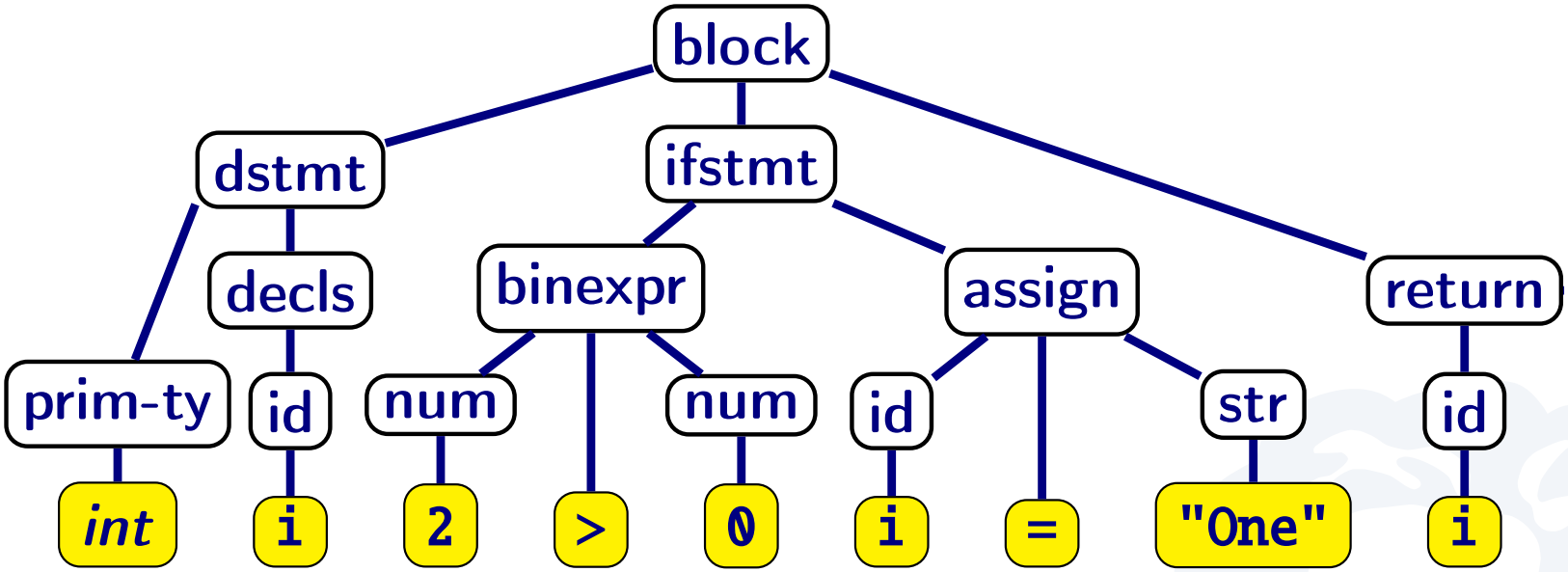
*Translate text files into **meaningful** in-memory structures*

- CST = Concrete Syntax Tree
  - Full "parse", cf. language BNF grammar
  - Not usually materialised in memory
- AST = Abstract Syntax Tree
  - Standard in-memory representation
  - Avoids syntactic sugar from CST, preserves important nonterminals as **AST nodes**
  - Converts useful tokens into attributes



Program analysis starts on the AST

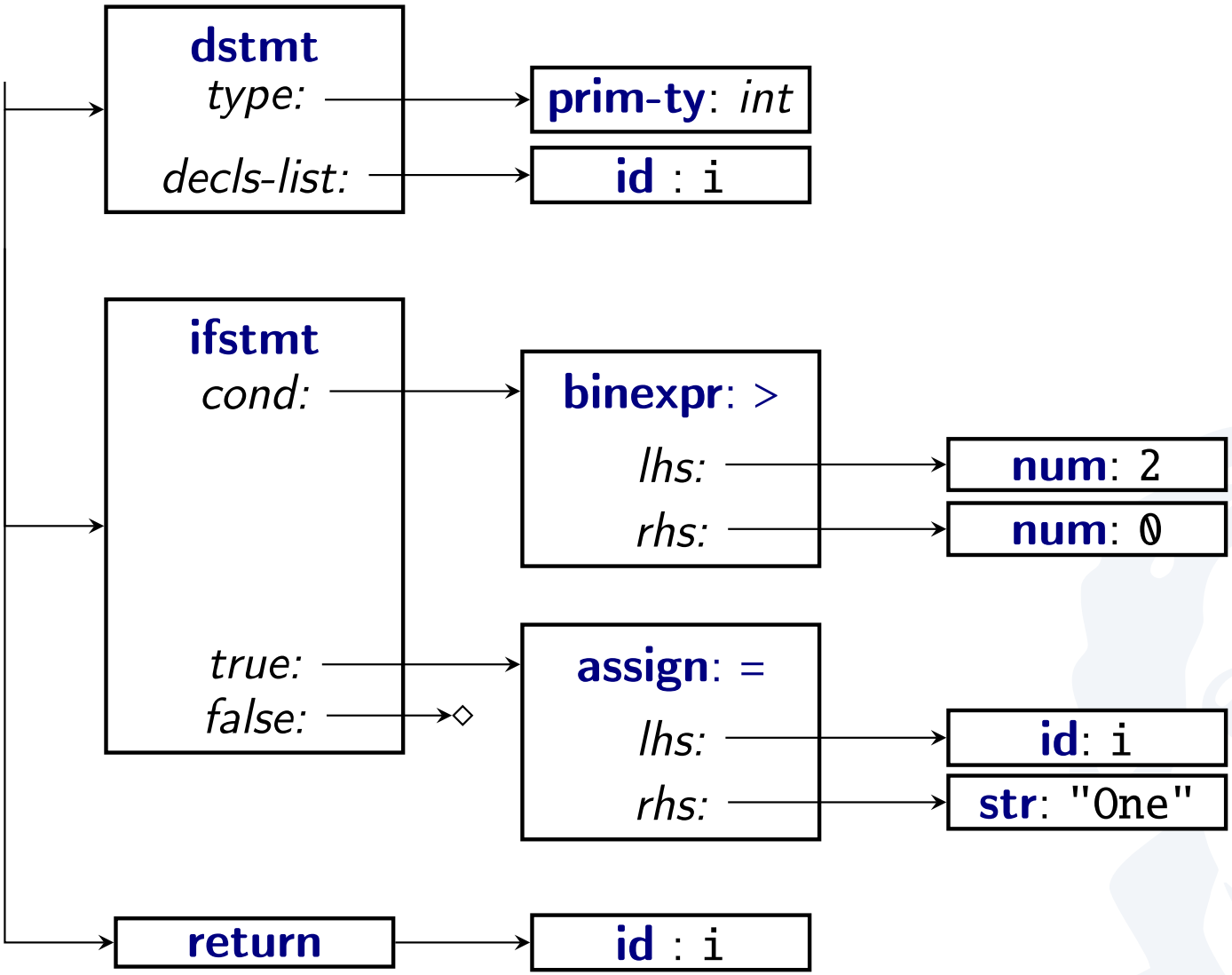
In-Memory Representation



Typical in-memory representations for this AST:

- Algebraic values (functional)
- Records (imperative)

In-Memory Representation

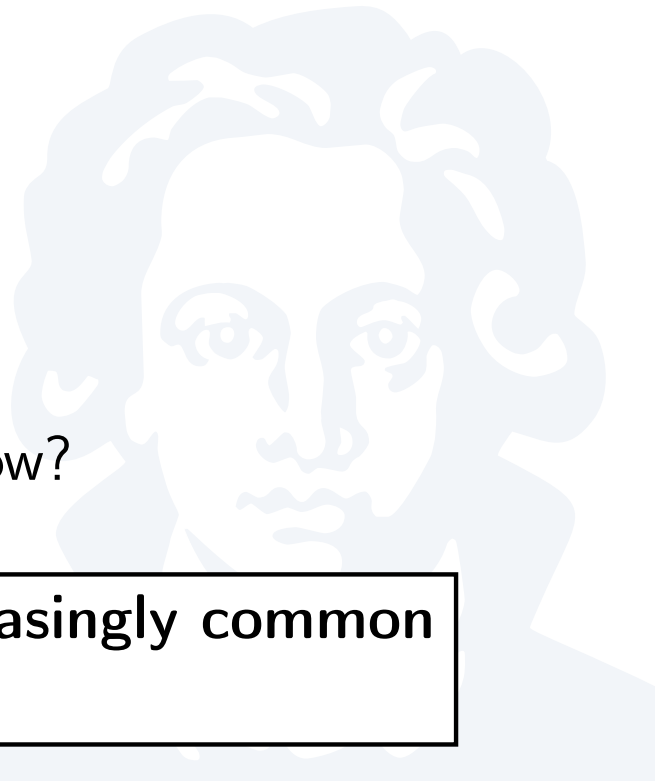


Program Analysis

We run numerous code analyses on the AST:

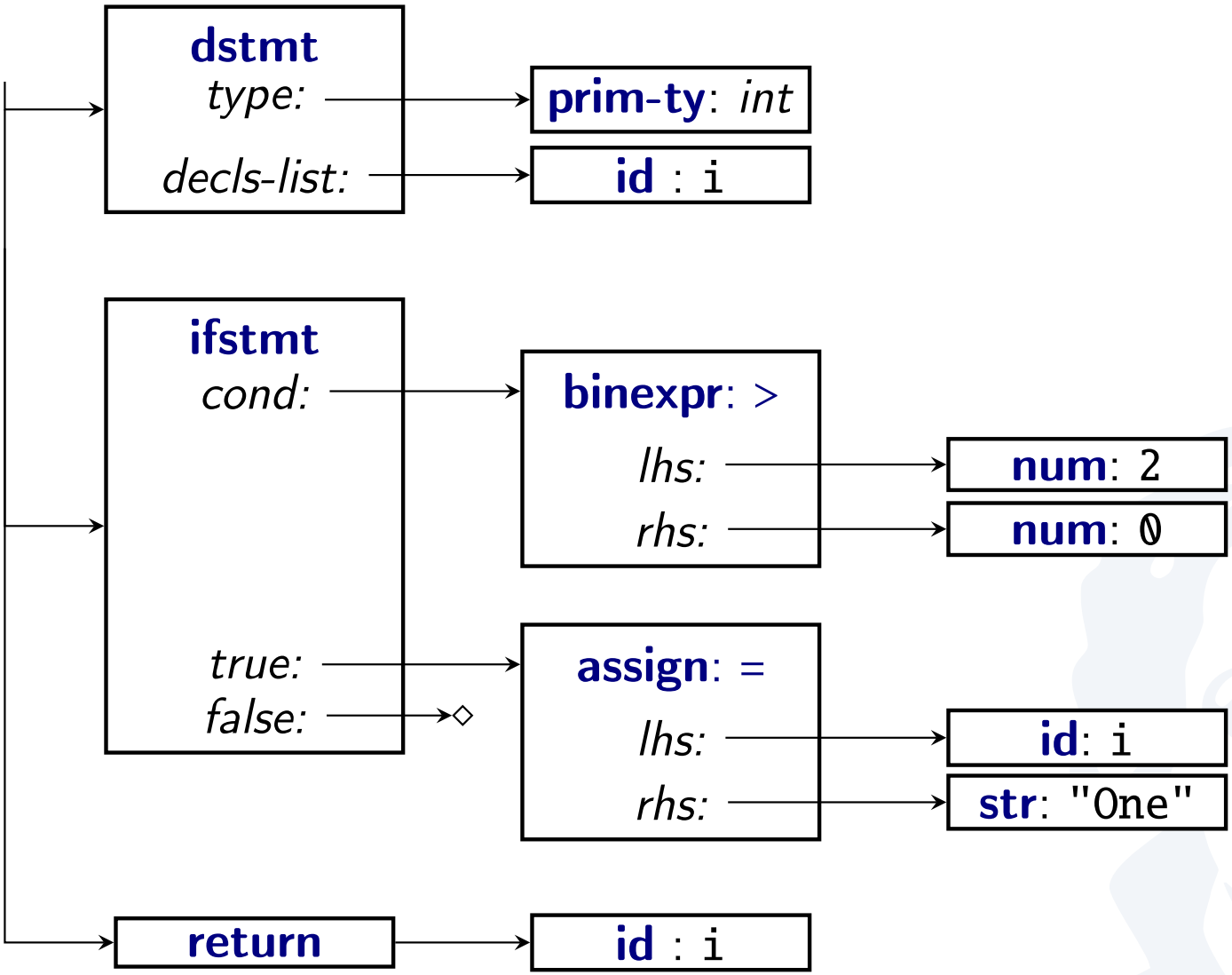
- *Name Analysis*:
  - Which name *use* binds to which *declaration*?
- *Type Analysis*:
  - What are the types of all expressions?
- *Static Correctness Checks*:
  - Are there type errors?
  - Is a variable unused?
  - Are we initialising all variables?

  ...
- *Optimisations*:
  - Can we speed up the program somehow?

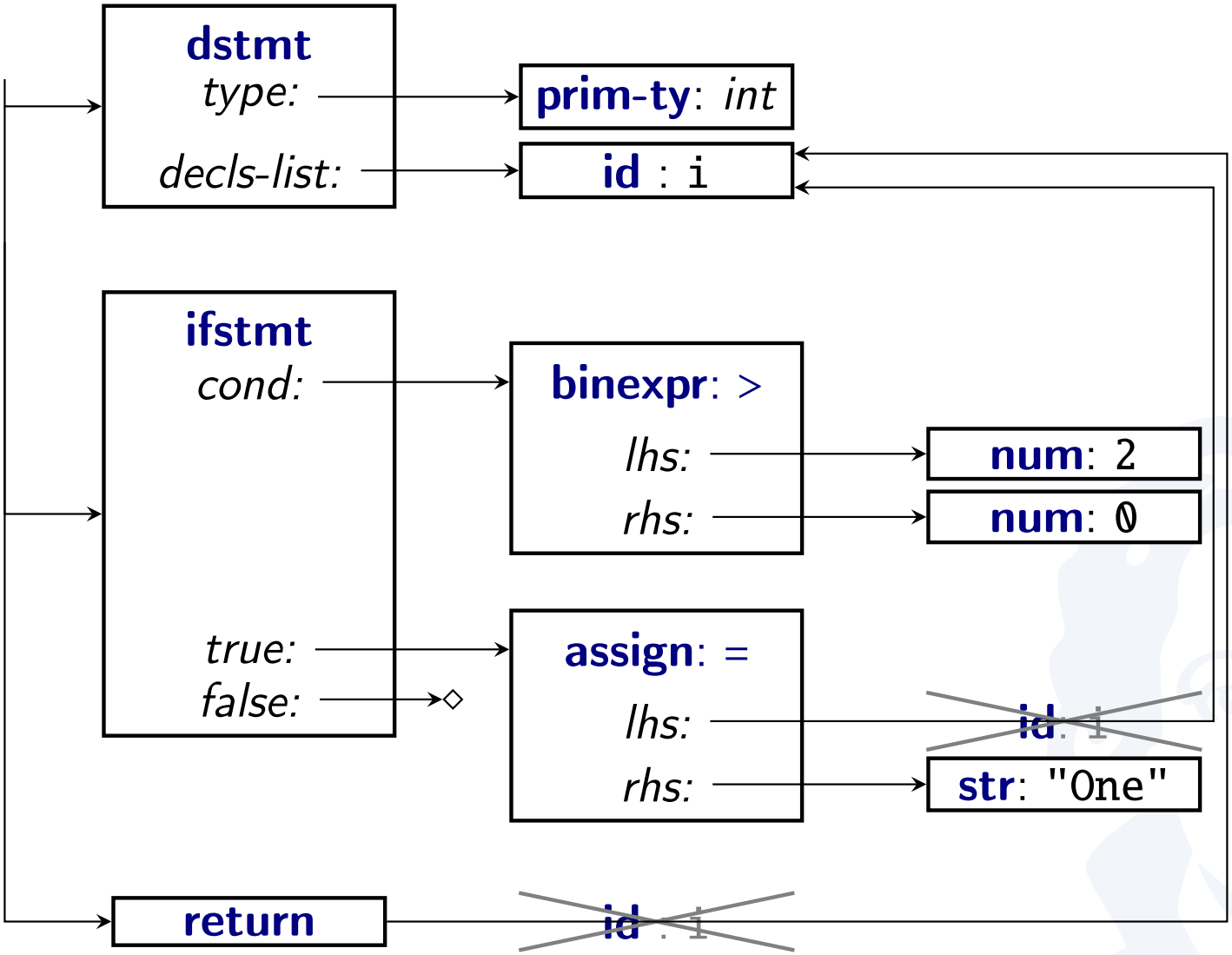


Advanced static correctness checks increasingly common in compilers

Name Analysis



Name Analysis



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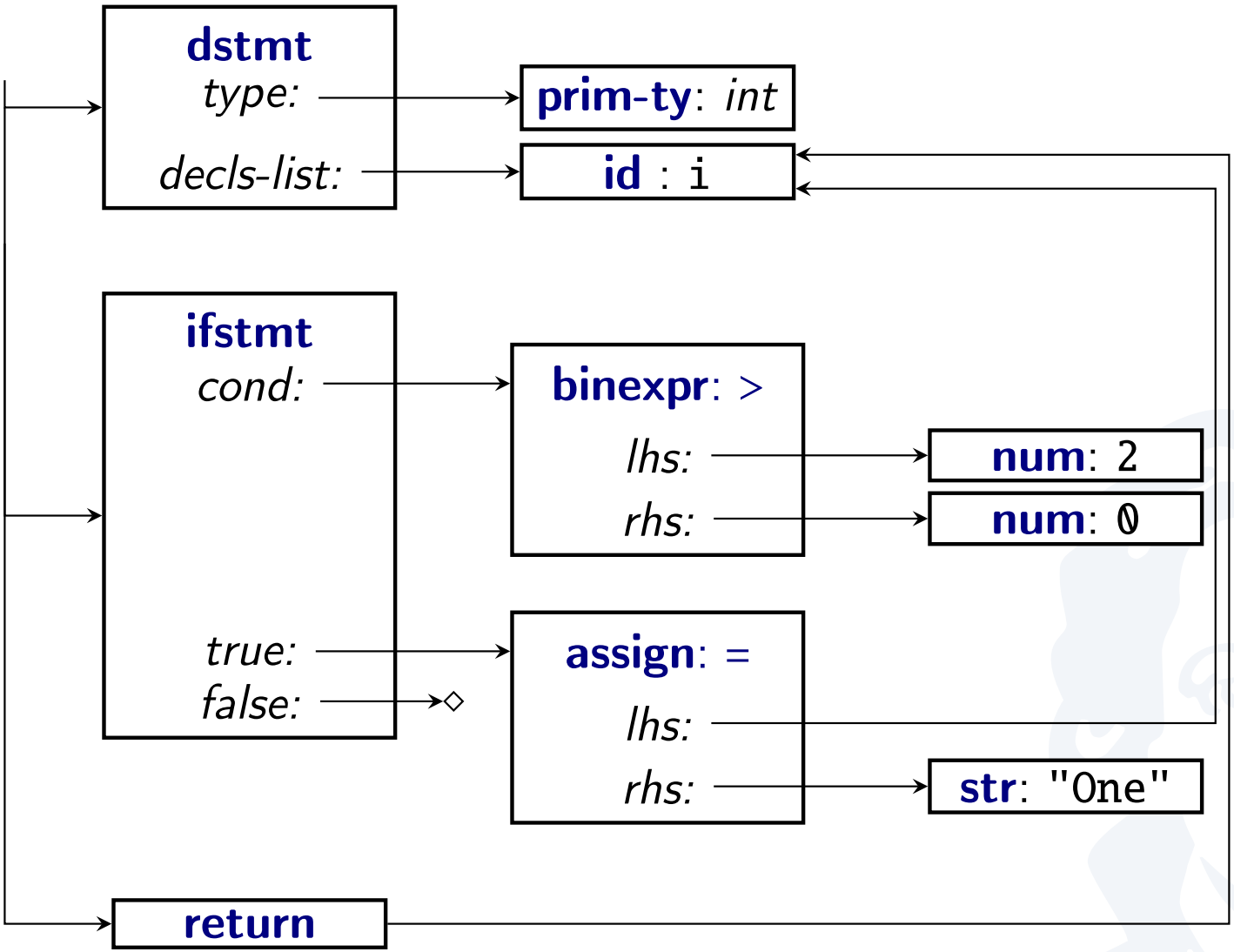

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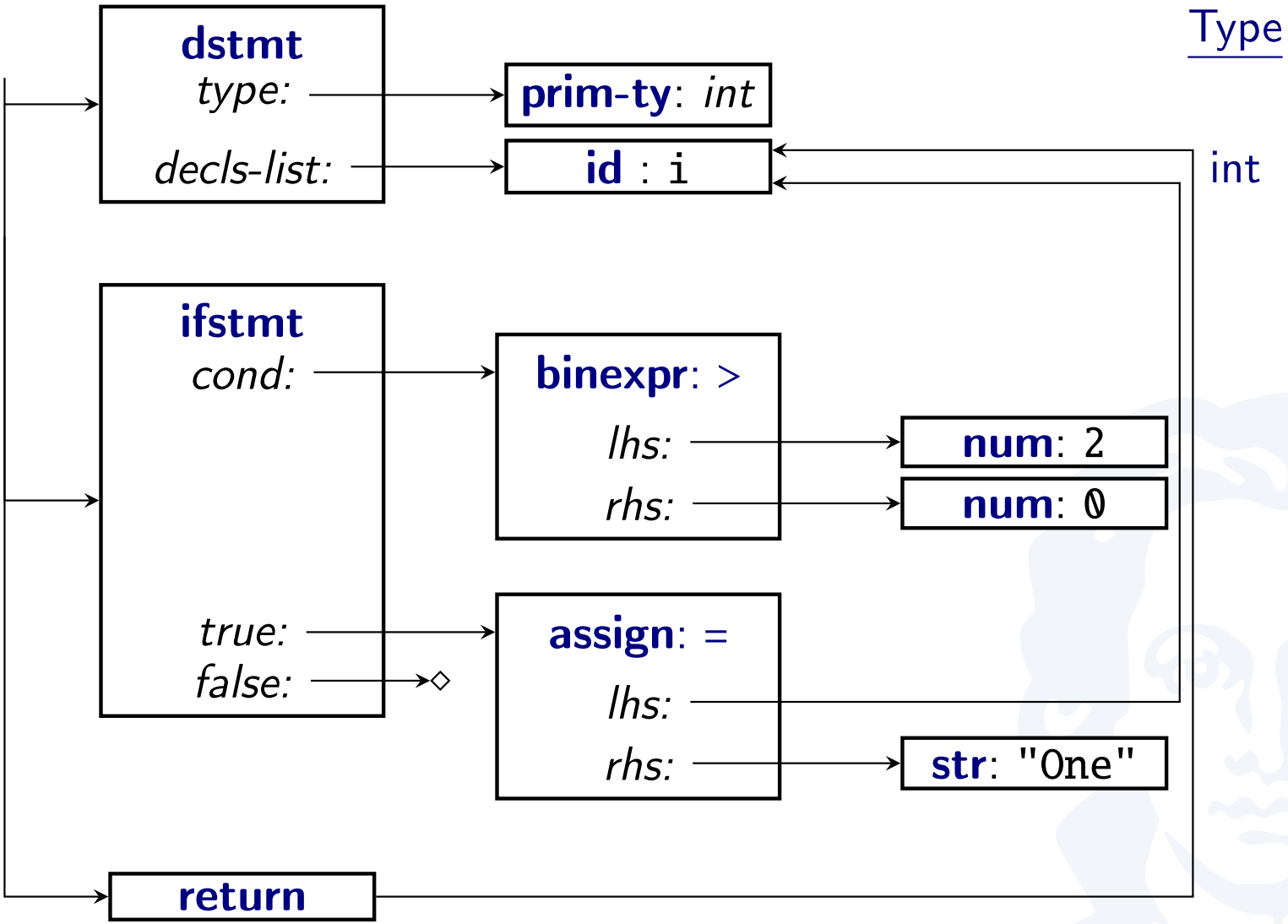

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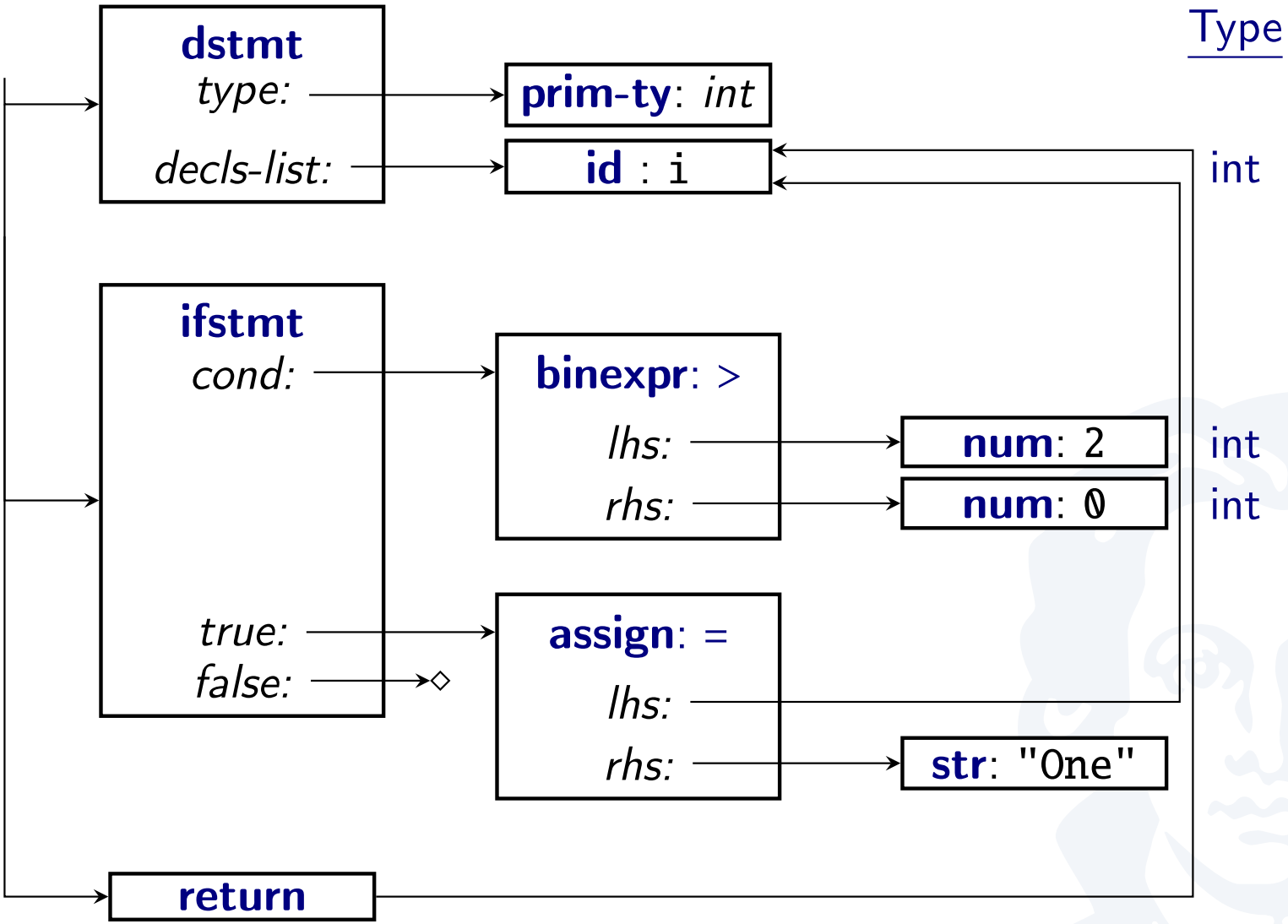

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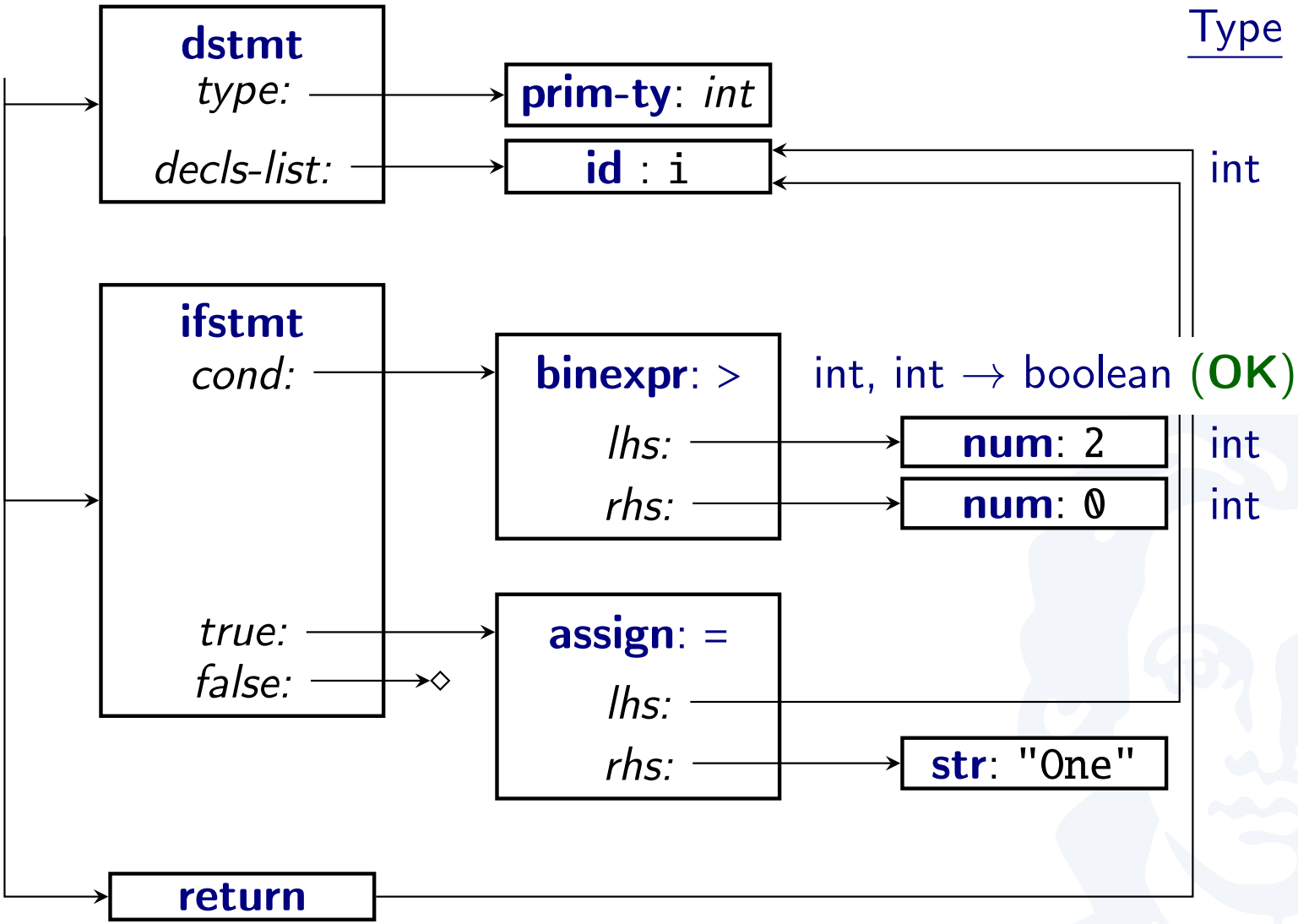

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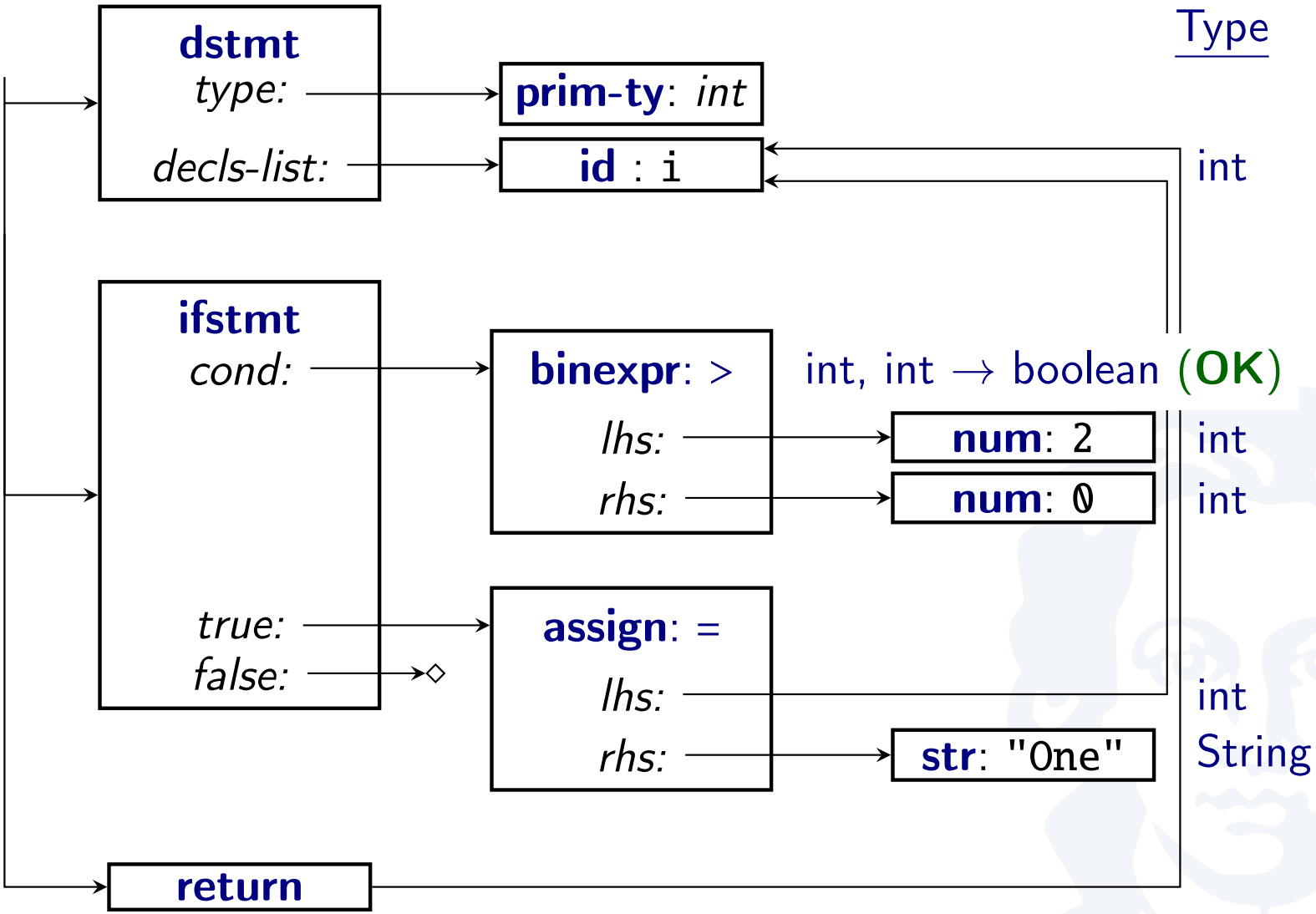

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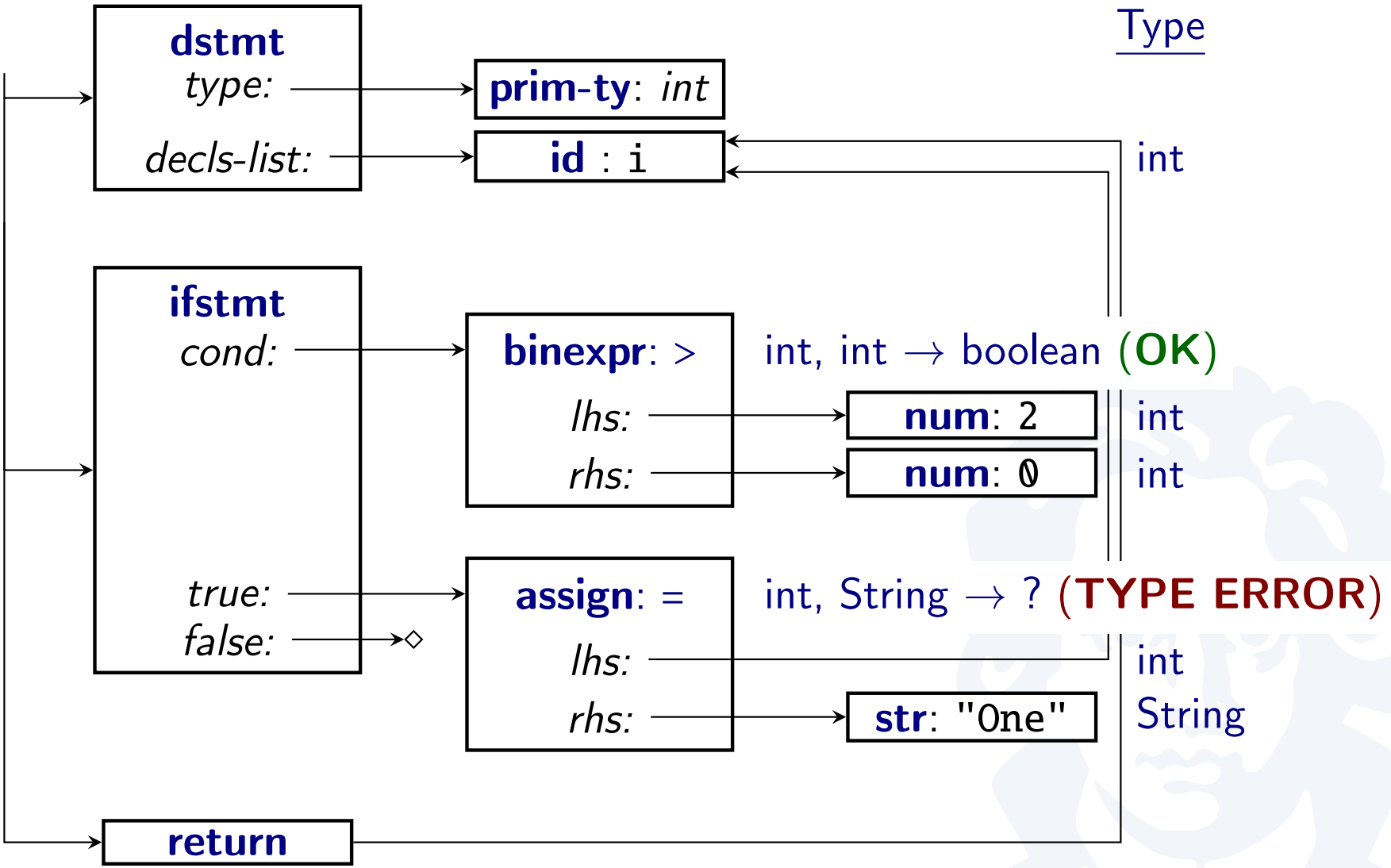

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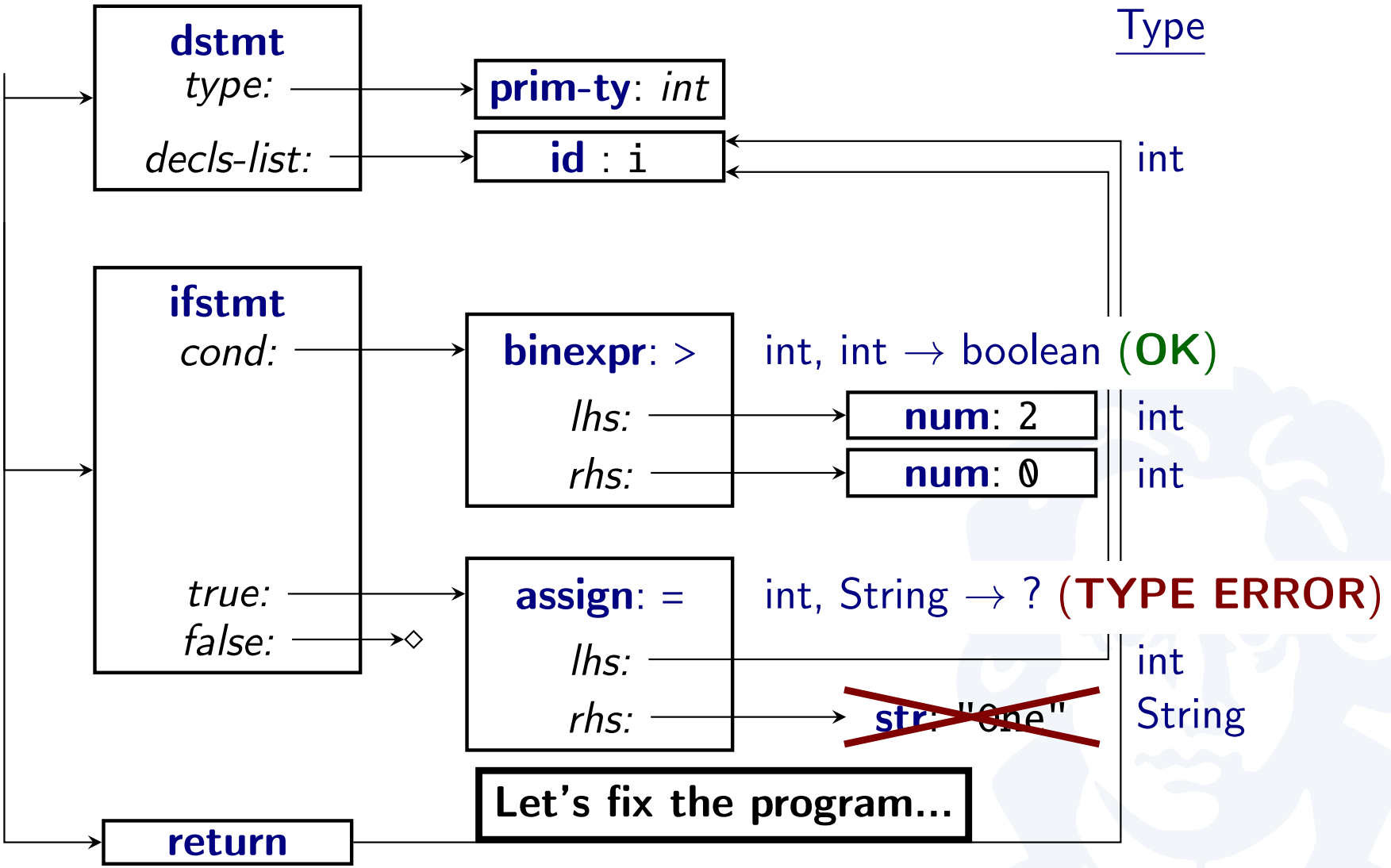

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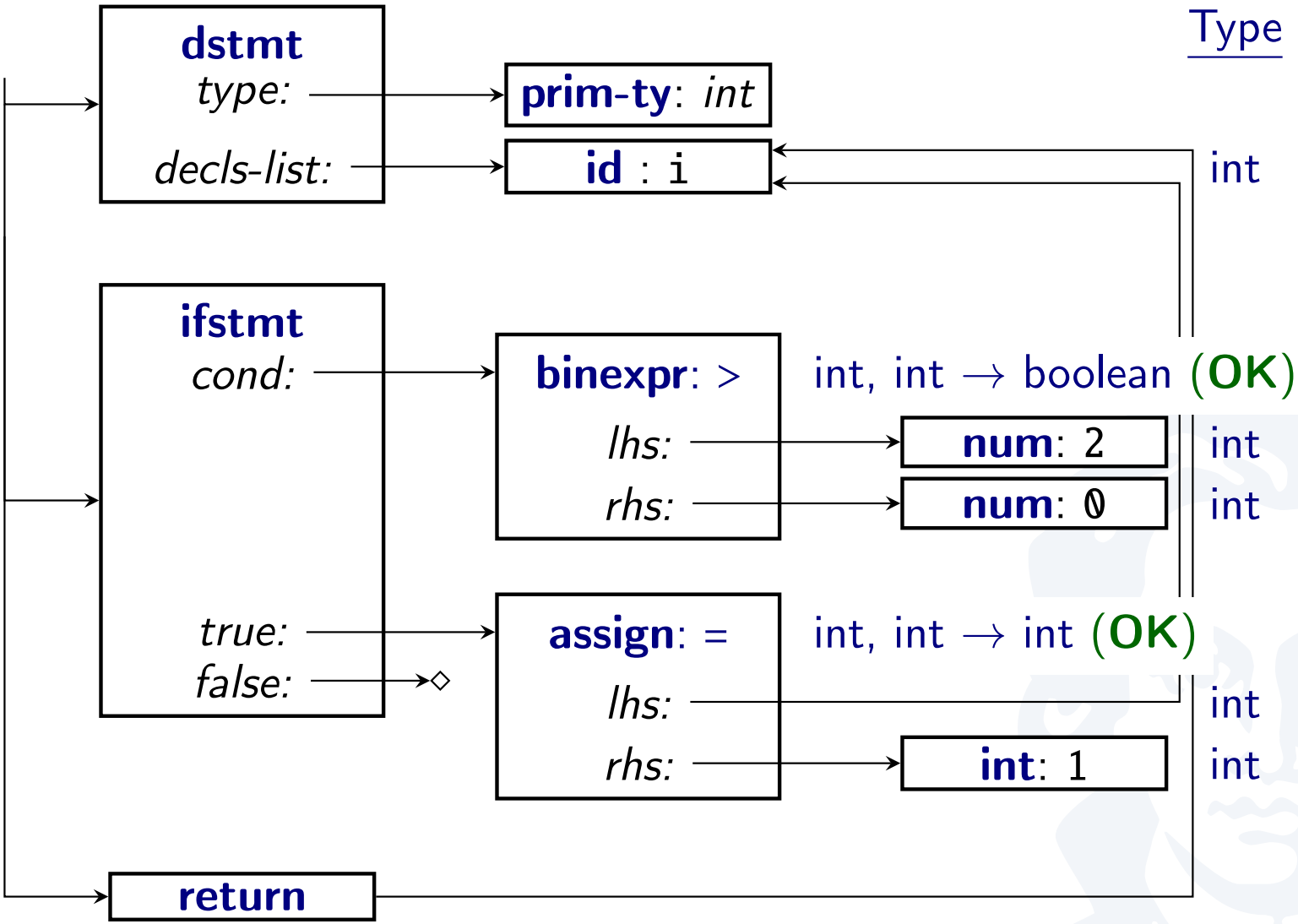

Summary

- Compiler represents programs in *intermediate representations* (IRs)
- Compiler can be separated into:
  - *Frontend*: process incoming source code, generate IR
  - *Middle-end*: optimise IR
  - *Back-end*: translate IR into executable code
- Parser matches *concrete syntax tree* (CST), generates *abstract syntax tree* (AST)
- Typical analyses on AST:
  - *Name analysis*: which variable use belongs to which definition?
  - *Type analysis*: do variable/operator/function types agree? Any implicit conversions needed?