Compiler Project

Semantic Analysis

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Outline

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Semantics of VSOP is given in the manual

Scoping rules.

- Where is a given variable, field or method accessible?
- Where does an identifier points to?

Typing rules.

- Are expressions of the right types for the operations?
- Are method calls consistent with their declarations?

Evaluation rules.

- What do VSOP expressions mean?
- How is VSOP code executed?

VSOP is statically typed

The compiler checks types at **compile time**. No type error can occur at runtime.

Every expression is assigned a type, according to developer annotations and VSOP typing rules.

Contrast this to dynamic languages like python, where

```
def f():
    return 40 + "two"
```

would crash at runtime, when (and only if) `f()` is actually called:

```
TypeError: unsupported operand types for +:
    'int' and 'str'
```

VSOP is Object-Oriented, with (single) inheritance

When

```
class Child extends Parent { ... }
```

`Child` inherits all fields and methods of `Parent` in addition to its own.

The type of `Child` **conforms to** the type of `Parent`, i.e. a `Child` *instance* can be used everywhere a `Parent` one can. A `Child` **is a** `Parent`. `Child` is a **subtype** of `Parent`.

In VSOP, it is illegal to redefine parent's fields, but you can **override** methods (with same *signature*).

Method dispatch is checked with declared type of object

```
class C extends P { onlyInC() : int32 { ... } }
                    // New method not in P

let o : P <-  // Declared/Static type is P
    if inputInt32() = 0 // Take int32 typed by user
        then new C  // `new C` valid here as C <: P
                    // Actual/Dynamic type is C
        else new P  // Actual/Dynamic type is P
in o.onlyInC(); // Type error! Static type is P
    // Would be valid if the user typed 0, but we
    // cannot tell at compile time
let o : P <- new C
in o.onlyInC(); // Type error: declared type still P
    // Always valid, but forbidden nonetheless
```

VSOP allows dynamic dispatch

```
class P { name() : string { "P" } }
class C extends P { name() : string { "C" } }

let o : P <- new C
in {
    o.name() // Will return "C", not "P"
}
```

Manipulating an identifier with the type of the parent class allows to only use the methods declared in the parent class (**statically typed**).

But if the object pointed by this identifier has the type of the child class, the method that will be called is the child's one (**dynamic dispatch**).

The Unit type

The type `unit`, of which only inhabitant is `()`, is an alternative to `void` in other languages. It is similar to `NoneType` in Python.

It is not specific to VSOP, but appears in many functional languages, which are often expression-based (e.g. Haskell, OCaml, SML, ... but also Kotlin, Rust, Swift, etc.).

As VSOP is statically typed, you don't need to actually represent `()` (for code generation). If something has type `unit`, then it can only have value `()`.

Why is it called `unit`? See *algebraic data types* (ADT) if curious.

Conditionals

In a conditional of the form

`if <expr_cond> then <expr_then> else <expr_else>`

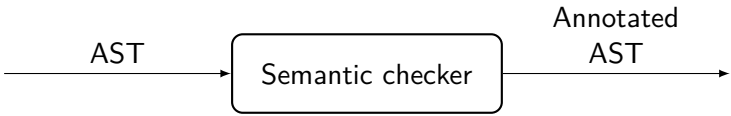
the condition `<expr_cond>` must be of `bool` type.

The types of both branches must **agree**:

- If both branches have class type, the types agree and the resulting type is the class of the first common ancestor.
- If both branches have the same primitive type, the types agree.
- If a branch has type `unit`, the types agree and the resulting type of the conditional is `unit`.
- Else, it is a typing error.

Outline

Semantic analysis



Converts bare AST into an *annotated* (**typed**) AST.

Due **at the latest** Tuesday the 19th of April.

Automated tests worth 5% of your grade.

Output format

Similar to the syntax analysis one, but the AST will be annotated with types for all expressions. For example

```
[Class(C, Object,
  [Field(a_string, string, "C" : string)],
  [Method(a_fun, [i : int32], unit,
    [Call(self : C, printInt32, [i : int32]) : Object,
     () : unit] : unit)]),
 Class(Main, Object, [],
       [Method(main, [], int32, [0 : int32] : int32)])]
```

You can (and should) keep other information in your *annotated* AST, but only types will be printed.

Error messages

Error messages should begin with:

`<filename>:<line>:<colon>: semantic error:`

Exact error positions are up to you (examples coming).

During semantic analysis, it is easy to give insightful error messages.

You can do error recovery using a *dummy* type.

Lexical and syntax errors must of course still be supported.

Outline

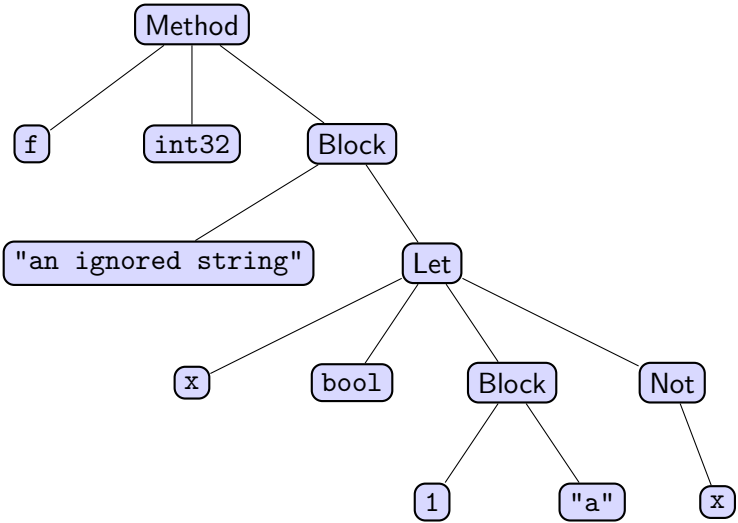
Bottom-up error reporting

```
class C {
    f() : int32 {
        "an ignored string";
        let x : bool <- { 1; "a" }
        in not x // Last block expression
    }
}
```

```
input.vsop:4:25: semantic error:
  expected type bool, but found type string.
input.vsop:2:17: semantic error:
  expected type int32, but found type bool.
```

First message complains that the type of `{ 1; "a"}` is not `bool`. The second complains that the whole method body should be of type `int32`.

Bottom-up error reporting



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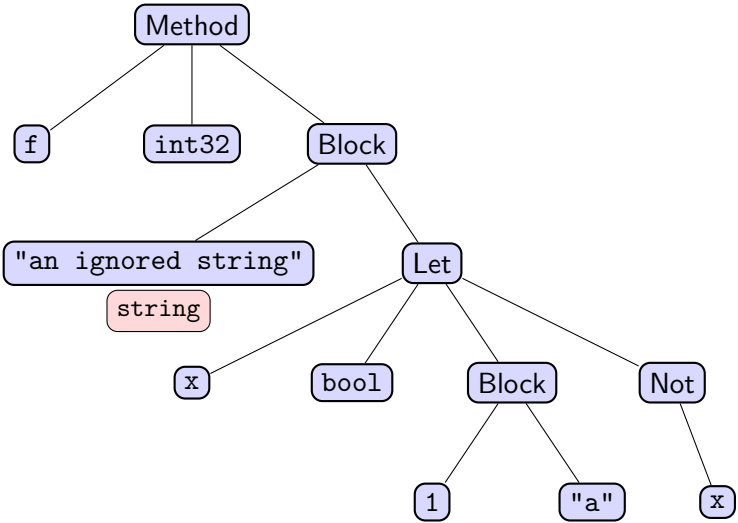

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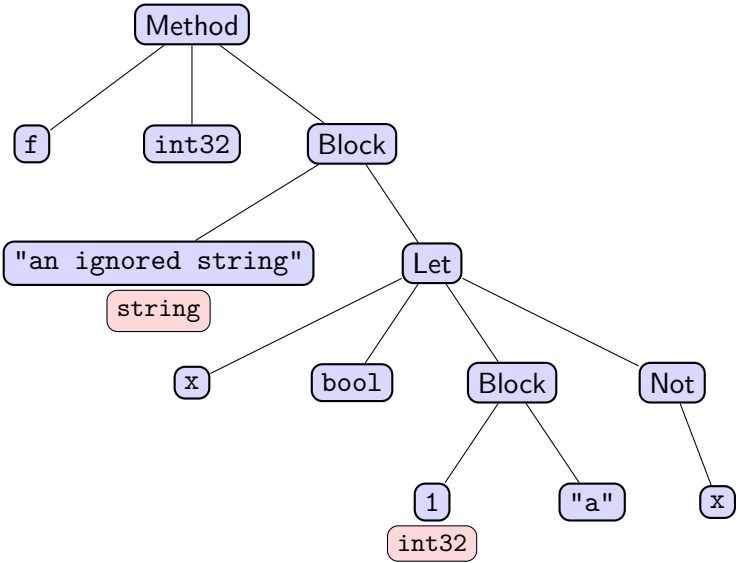

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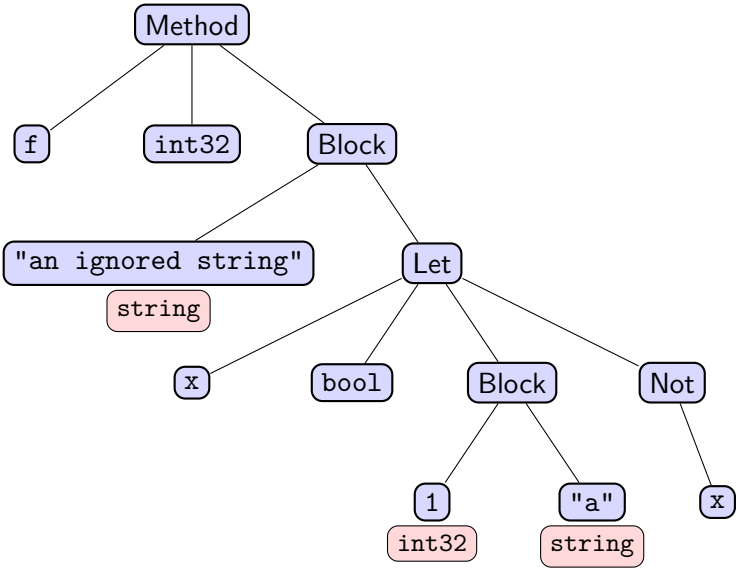

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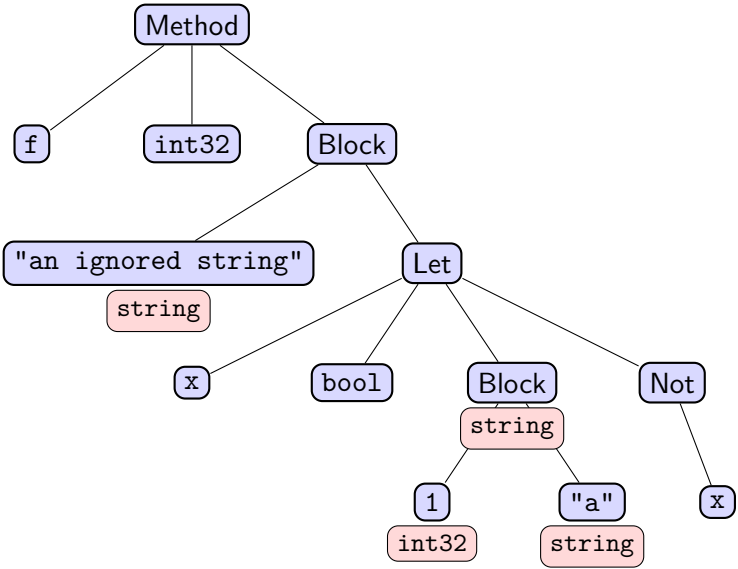

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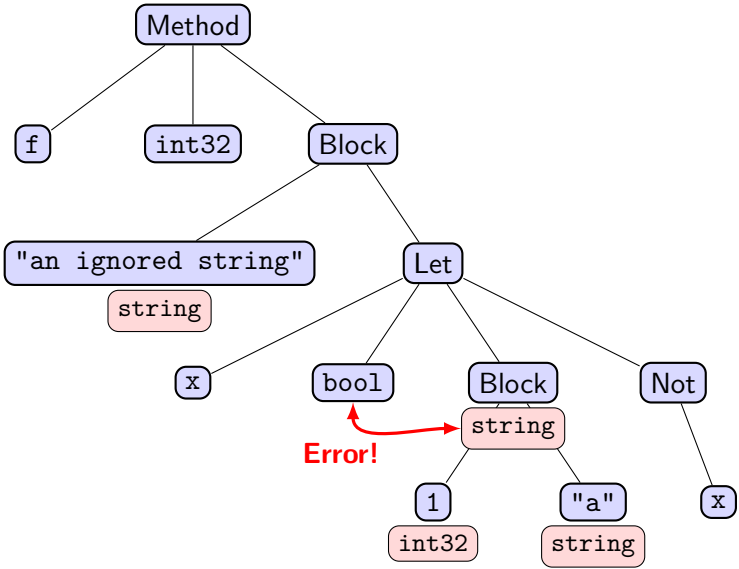

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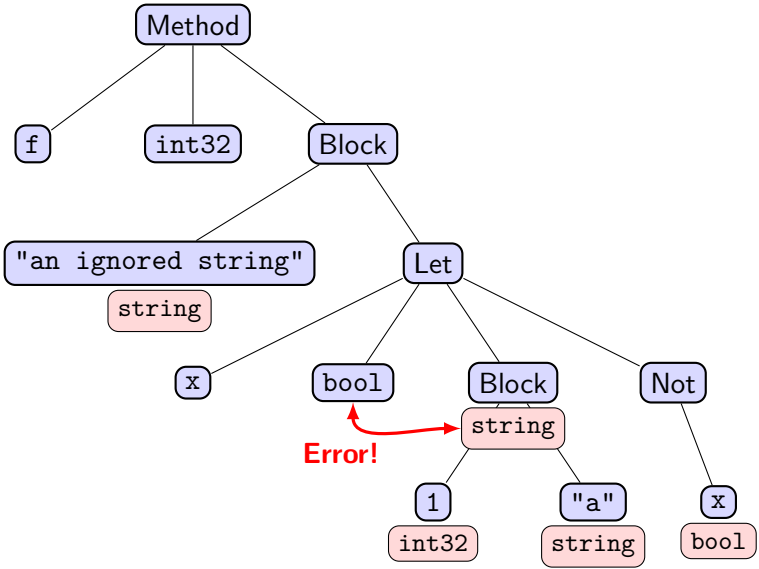

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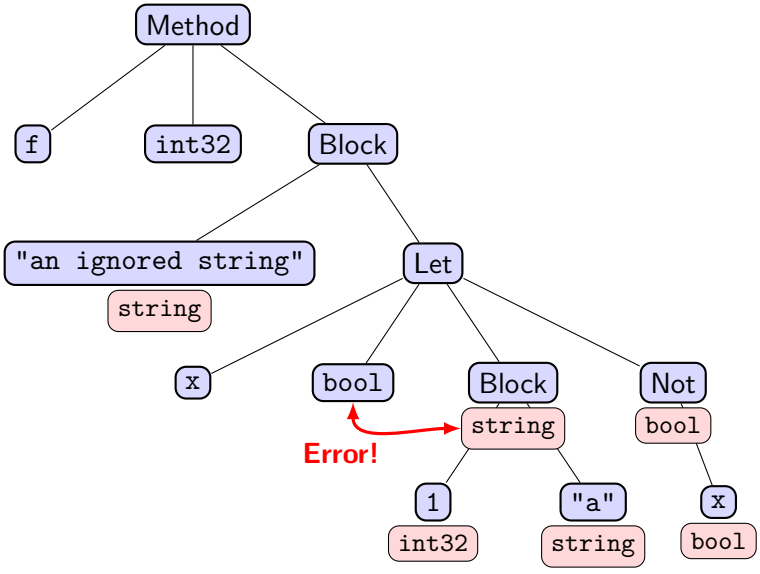

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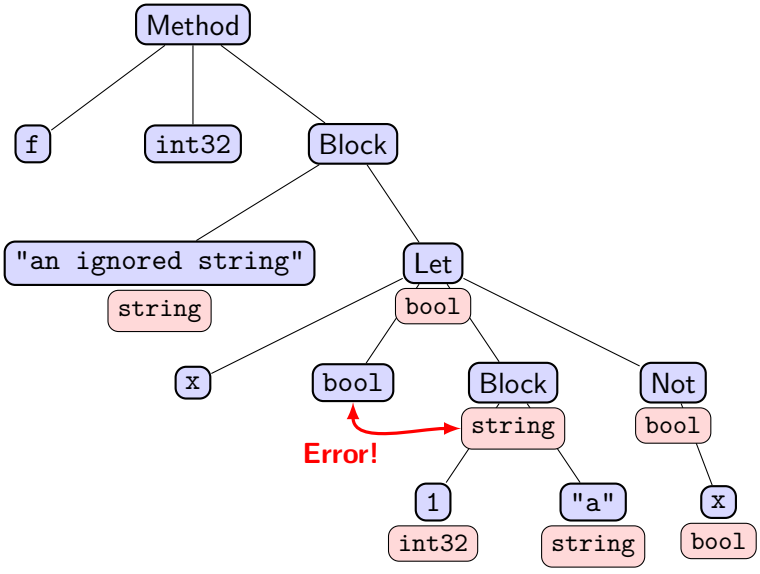

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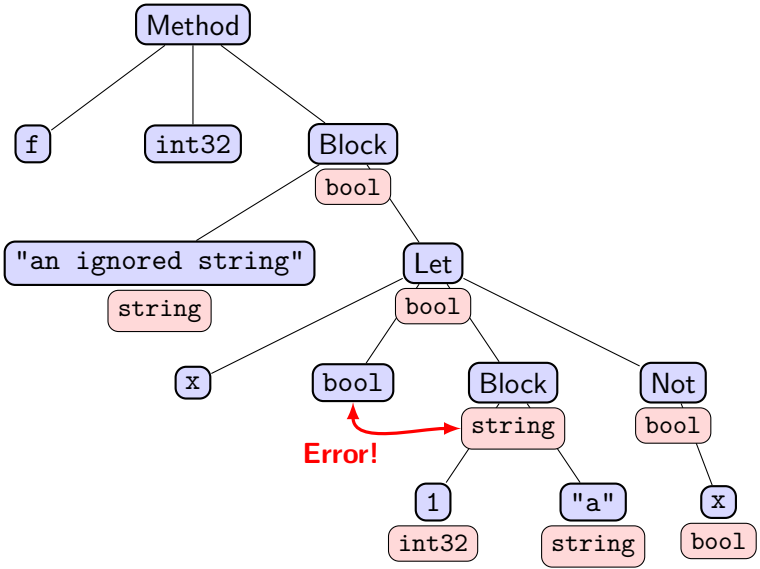

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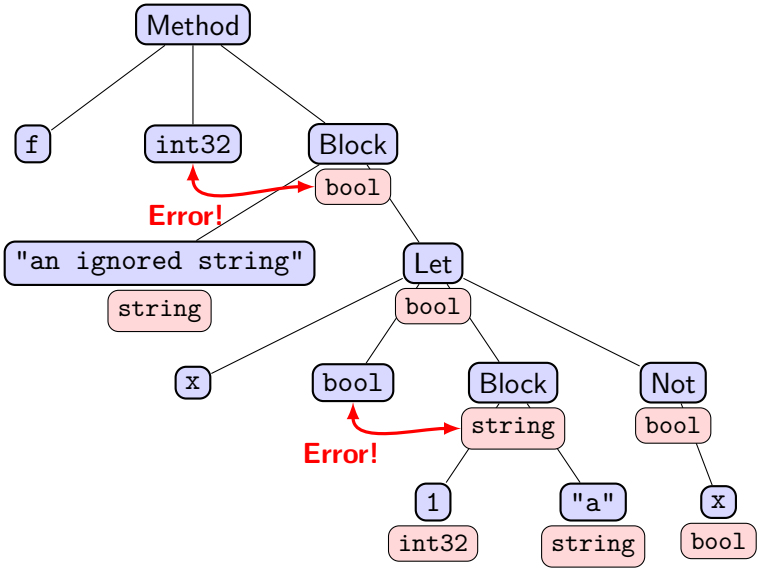

Top-down error reporting

```
class C {
    f() : int32 {
        "an ignored string";
        let x : bool <- { 1; "a" }
        in not x // Last block expression
    }
}
```

```
input.vsop:4:30: semantic error:
  expected type bool, but found type string.
input.vsop:5:12: semantic error:
  expected type int32, but found type bool.
```

First message reports the position of `"a"`, while the second report the position of `not x`.

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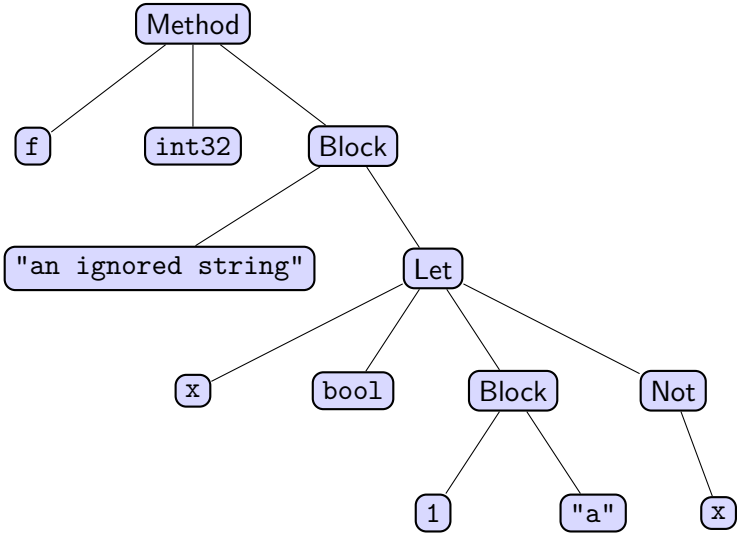

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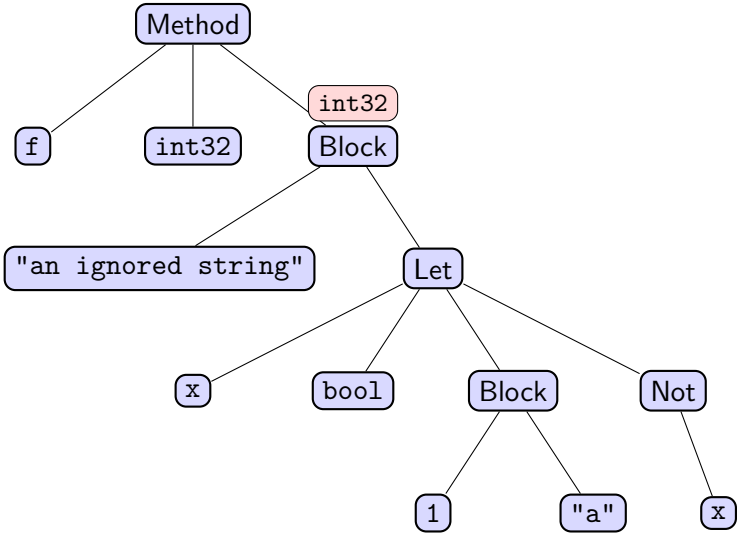

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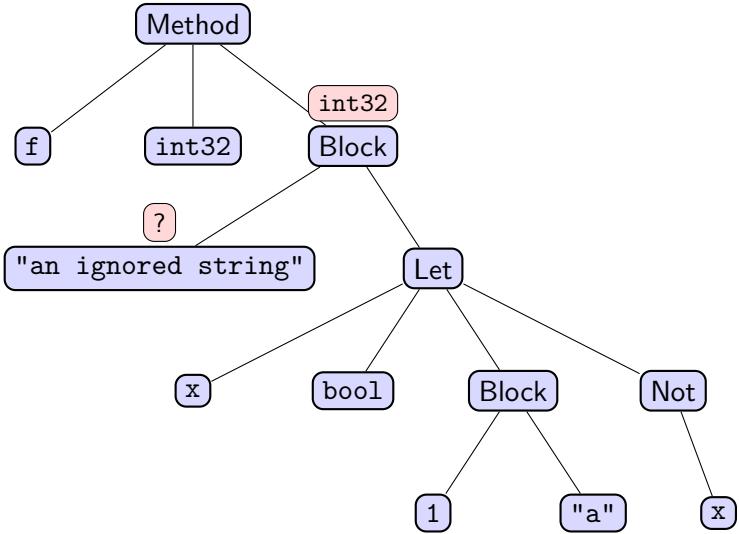

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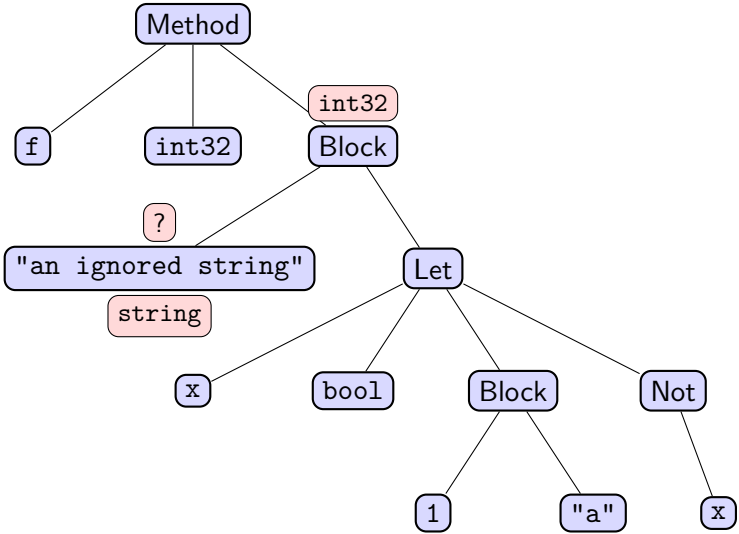

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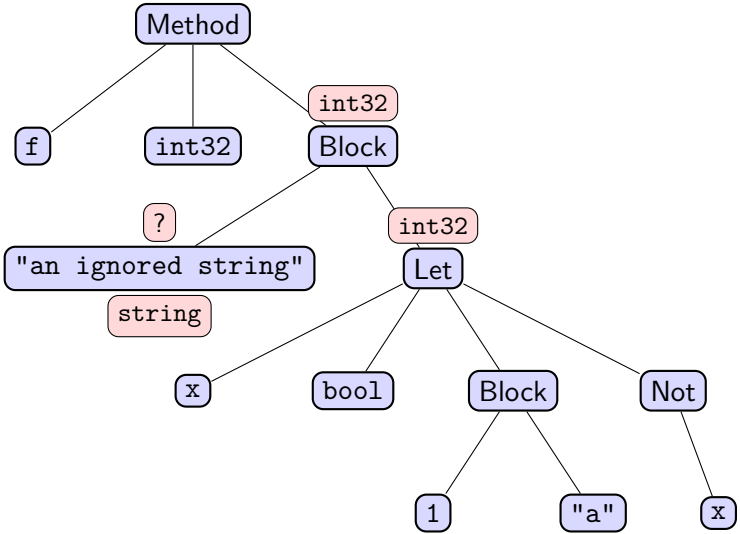

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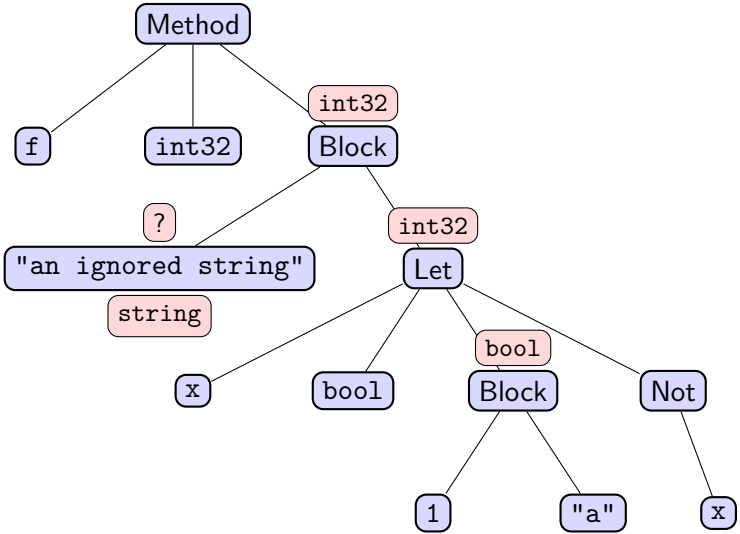

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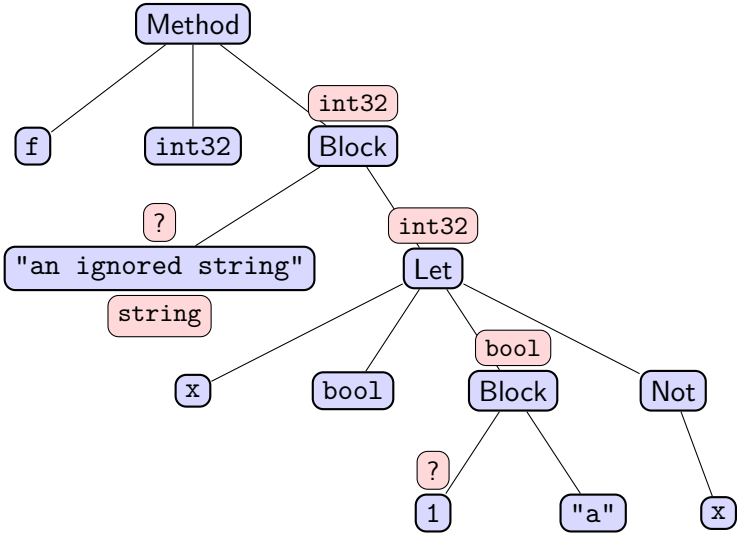

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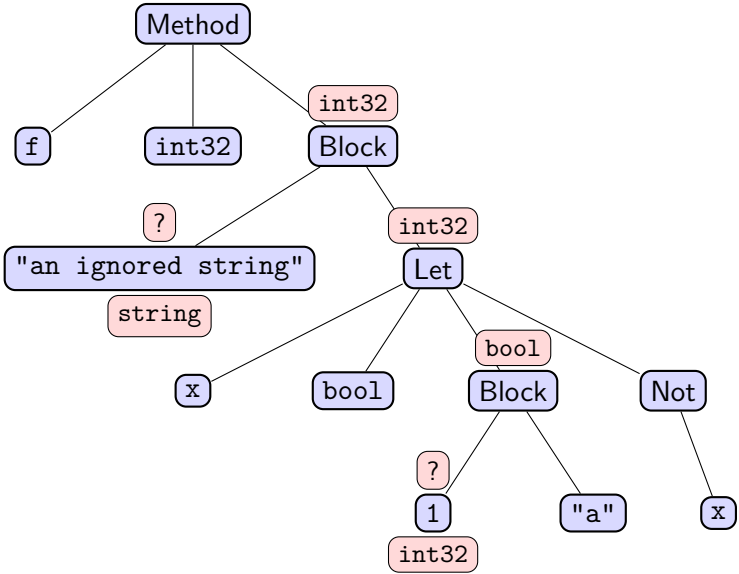

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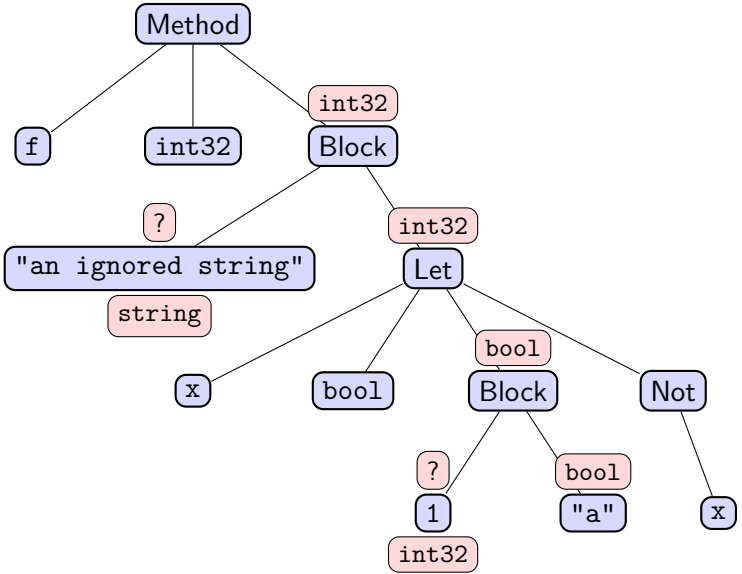

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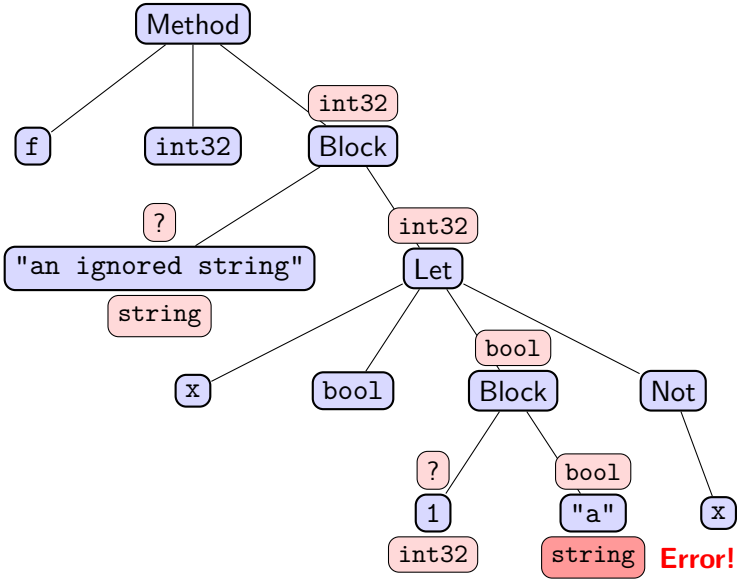

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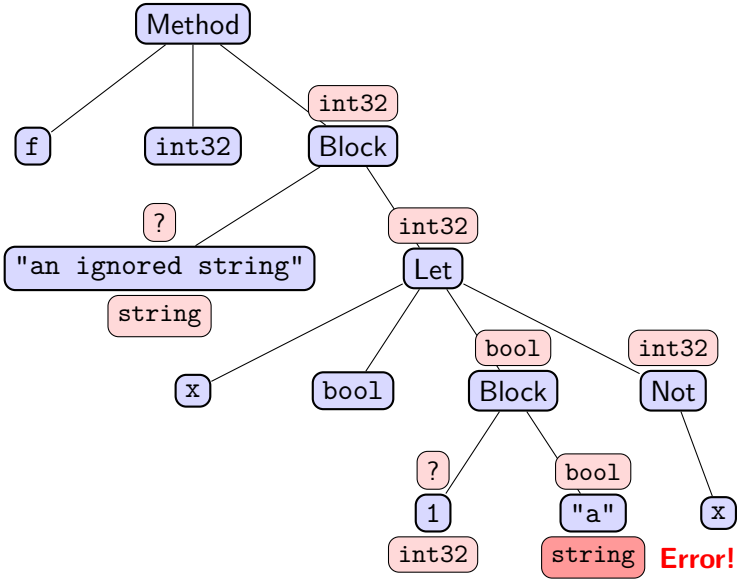

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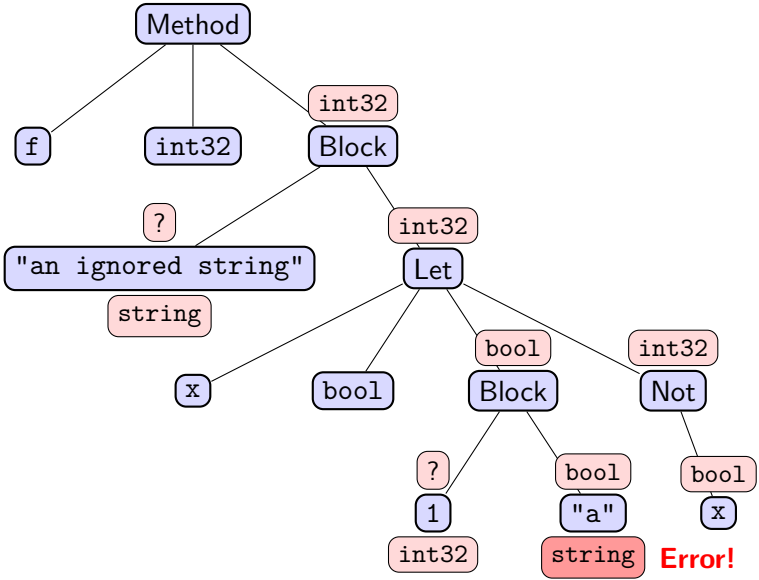

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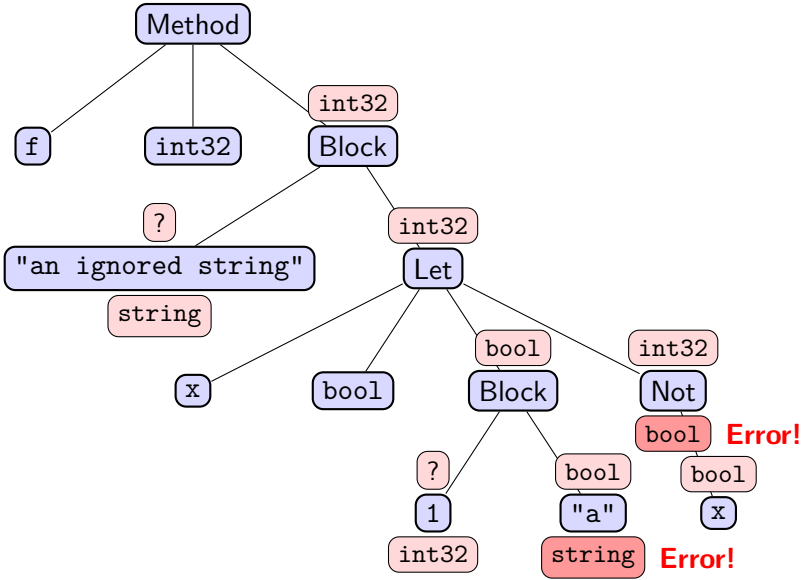

Make multiple passes

Order of declarations does not matter in VSOP, and it is hard to analyze a VSOP program in one pass. For example

```
class C extends P { ... }
// many other classes ...
class P { ... }
```

On line 1, is `P` defined? Is it a child of class `C`? You need information from the whole file.

Similar issue with method and fields declarations.

You could try to be smart (e.g. queue checks to be done), but it is not worth it. KISS and do **as many passes as needed**.

However, in VSOP, the expected type of an expression is often known before inspecting the expression itself.

Questions and (Possibly) Answers