Compiler Project

Syntax Analysis

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Outline

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Syntax Analysis Converts Tokens to a Parse Tree

Converts a stream of tokens into
an **abstract syntax tree** (AST)

Detects syntactically invalid source code

Assignment

You can use a **parser generator**
(e.g. bison, CUP, PLY, ANTLR, parsec)

Automated tests worth 5% of your grade

Support for custom tests in `tests` subfolder

Two modes: `-p` and `-l`

Due Tuesday the 15th of March

Output Format

```
[Class(List, Object, [],
       [Method(isNil, [], bool, true),
        Method(length, [], int32, 0)]),
 Class(Nil, List, [], []),
 Class(Cons, List, [Field(head, int32),
                    Field(tail, List)],
       [Method(init, [hd : int32, tl : List], Cons,
               [Assign(head, hd),
                Assign(tail, tl), self]),
        Method(head, [], int32, head),
        Method(isNil, [], bool, false),
        Method(length, [], int32,
               BinOp(+, 1, Call(tail, length, [])))]),
```

Error Management

Error messages on `stderr`, fail with code $\neq 0$

`input_file.vsop:4:12: syntax error: DESCRIPTION`

Tests do not check the positions

Automated tests don't check the description, but we do!

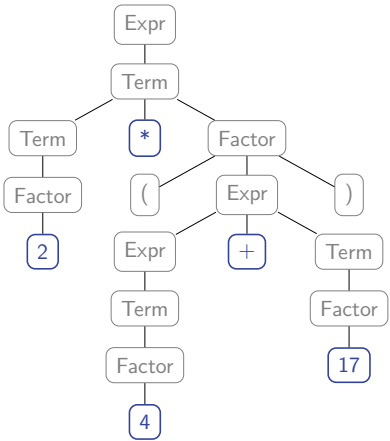
Syntax error reporting is challenging, see lectures!

Lexical errors can still happen!

Questions and (Possibly) Answers

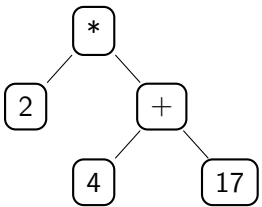
Outline

A Concrete Parse Tree Is Very Redundant



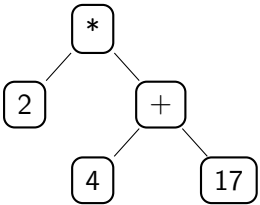

```
2 * (4 + 17)
```

Use an Abstract Syntax Tree (AST)

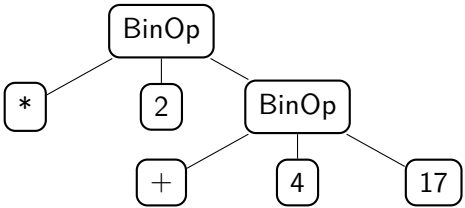



```
2 * (4 + 17)
```

Use an Abstract Syntax Tree (AST)

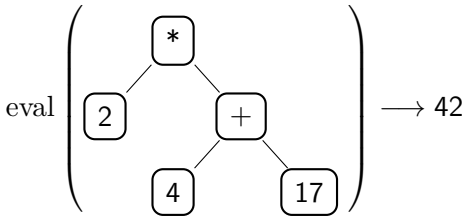



```
2 * (4 + 17)
```



Processing Abstract Syntax Trees

Example: evaluating arithmetic expressions



In your compiler:

- Print the tree (AST dump)
- Annotate tree with types
- Code generation

Avoid Generic Trees

```
class ASTNode {
    private List<ASTNode> children;
    private String value;
    ...
    public double eval() {
        if (children.length() == 3) {
            if (children.get(1).value == "+") {
                return children.get(0).eval()
                    + children.get(2).eval();
            } else if ...
```

Seems economical, but hard to read and **error-prone**

OO Inheritance-based Approach

```
abstract class Expr { public abstract double eval(); }
class Add extends Expr {
    Expr lhs;
    Expr rhs;
    ...
    public double eval() {
        return lhs.eval() + rhs.eval();
    }
}
class Sub extends Expr {
```

Simple, good encapsulation, easy to add new nodes

Logic of a pass spread across many classes, Inheritance has a cost

Functional Approach

```
data Expr = Num Double | Add Expr Expr | Sub Expr Expr
          | ...

eval (Num num) = num
eval (Add lhs rhs) = eval lhs + eval rhs
eval (Sub lhs rhs) = eval lhs - eval rhs
...
```

Pass logic in a single file: Easier to add passes, to read

No information hiding, less flexible than OO

Simulate Functional with Tagged Unions: Types

```
typedef enum { NUM, ADD, SUB, ... } Tag;
typedef struct Expr Expr;
typedef struct { double value } Num;
typedef struct { const Expr *lhs; const Expr *rhs; } Add;
...
struct Expr {
    Tag tag;
    union {
        Num num;
        Add add;
        Sub sub;
        ...
    };
};
```

Simulate Functional with Tagged Unions: Constructors

```
static Expr *new_expr(Tag tag) {
    Expr *ret = checked_malloc(sizeof (Expr));
    ret->tag = tag;
    return ret;
}
Expr *new_num(double value) {
    Expr *ret = new_expr(NUM);
    ret->num.value = value;
    return ret;
}
Expr *new_add(const Expr *lhs, const Expr *rhs) {
    Expr *ret = new_expr(ADD);
    ret->add.lhs = lhs;
    ret->add.rhs = rhs;
    return ret;
}
```

Simulate Functional with Tagged Unions: Use

```
double eval(const Expr *e) {
    switch (e->tag) {
        case NUM:
            return e->num.value;
        case ADD:
            return eval(e->add.lhs) + eval(e->add.rhs);
        case SUB:
            return eval(e->sub.lhs) - eval(e->sub.rhs);
        ...
    }
}
```

Simulate Functional with Tagged Unions: Use

```
double eval(const Expr *e) {
    switch (e->tag) {
        case NUM:
            return e->num.value;
        case ADD:
            return eval(e->add.lhs) + eval(e->add.rhs);
        case SUB:
            return eval(e->sub.lhs) - eval(e->sub.rhs);
        ...
    }
}
```

Simple and efficient, no inheritance

Not type-safe (every type in single class)

Simulating Functional Approach with Introspection Is Generally Slow

```
double eval(Expr e) {
    if (e instanceof Num) {
        return ((Num) e).getValue();
    } else if (e instanceof Add) {
        Add add = (Add) e;
        return eval(add.getLeft()) + eval(add.getRight());
    } else if (e instanceof Sub) {
        ...
```

Java's `instanceof` operator is expensive

Long chain of `if-else if` $\implies \mathcal{O}(n)$ checks per node!

Except in selected languages (e.g. Darts)

The Visitor Design Pattern

Check if you want, but a bit overkill (on my opinion)

Idea: separate the objects from the functions that manipulate it:

- `Expr` is an abstract class for the objects
- `Visitor` is an abstract class for manipulating the objects

The Visitor Design Pattern: Interface

```
interface Visitor<R> {
    public R visit(Num num);
    public R visit(Add add);
    public R visit(Sub sub);
    ...
}
```

An `interface` with one `visit` method per AST node.

Parameterized over return type.

The Visitor Design Pattern: accept()

```
abstract class Expr {
    abstract public <R> R accept(Visitor<R> v);
}
class Num extends Expr {
    public <R> R accept(Visitor<R> v) {
        return v.visit(this);
    }
    ...
}
class Add extends Expr {
    public <R> R accept(Visitor<R> v) {
        return v.visit(this);
    }
    ...
}
```

The Visitor Design Pattern: Use

```
class EvalVisitor implements Visitor<Double> {
    public Double visit(Num num) {
        return num.getValue();
    }
    public Double visit(Add add) {
        return add.lhs.accept(this) + add.rhs.accept(this);
    }
    public Double visit(Sub sub) {
        return sub.lhs.accept(this) - sub.rhs.accept(this);
    }
    ...
}
```

The Visitor Design Pattern: Use

```
class EvalVisitor implements Visitor<Double> {
    public Double visit(Num num) {
        return num.getValue();
    }
    public Double visit(Add add) {
        return add.lhs.accept(this) + add.rhs.accept(this);
    }
    public Double visit(Sub sub) {
        return sub.lhs.accept(this) - sub.rhs.accept(this);
    }
    ...
}
```

Functional, type-safe, double dispatch faster than introspection

Little boilerplate, slightly heavy syntactically

Questions and (Possibly) Answers

Outline

Using Bison with C++

Like Flex, Bison has an option to generate C++ code.

This allows to use C++ classes inside your parser, among other things

There are some good tutorials online.

When creating your parser, proceed sequentially:

1. Create the grammar and remove all the conflicts
2. Link your parser with your lexer
3. Add the code to build your AST

You will probably have to change a bit your lexer to make it compatible with bison