Compiler Construction: Lexical analyses

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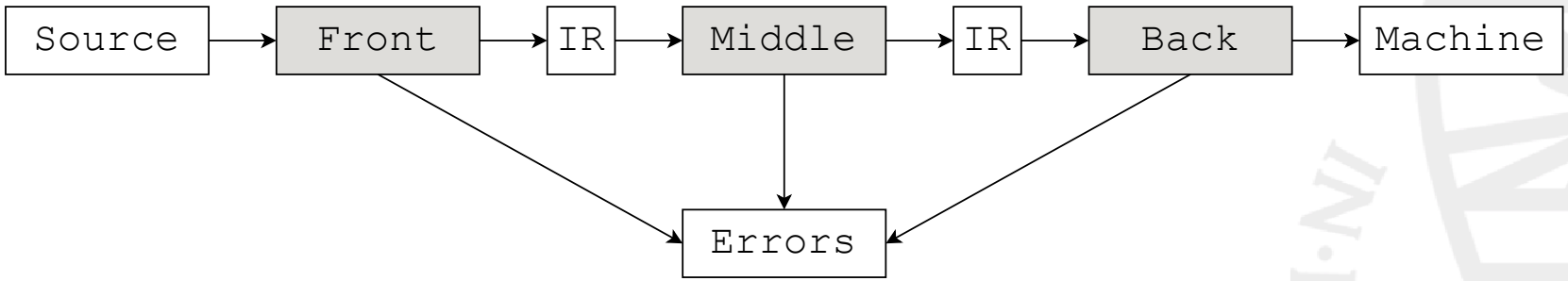
What was a compiler again?



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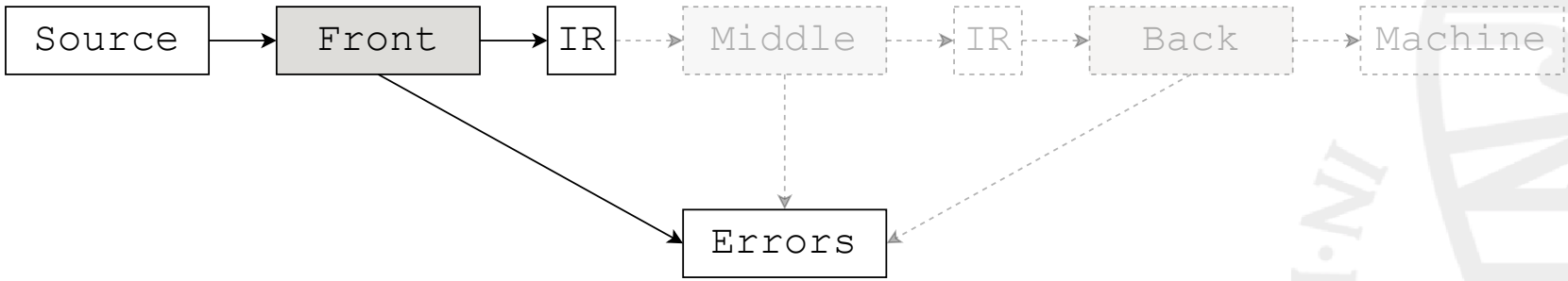

The goal

- **Given some arbitrary string of characters,**
- analyse this string,
- produce an abstract syntax tree,
- or give an error.

String of characters: Examples

```
sum(l:[Int]): Int {
  if (isEmpty(l.tl)) {
    return l.hd;
  }

  return l.hd + sum(l.tl);
}
```

String of characters: Examples

```
product(list:[Int]): Int {
  if (isEmpty(list)) {
    return 1;
  }

  return list.hd * product(list.tl);
}
```

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product(list:[Int]: Int {
  if (isEmpty(list)) {
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Analysis: Haskell

We chose *Haskell* to implement our parser (and the rest of our compiler):

- Algebraic data types;
- High level of abstraction;
- Good tooling and library support;
- **Functional parser combinators**.

Analysis: Functional parser combinators

Parser combinators work through *function composition*.

Analysis: megaparsec

The Andromeda Galaxy is roughly one **megaparsec** away (Torben Hansen, CC-BY-2.0).

Analysis: megaparsec

- Informal successor of Parsec;
- Does much of the heavy lifting;
- Large collection of combinators;
- Decent error messages out-of-the-box;
- `makeExprParser`.

Analysis: Tokenless parsing

We decided to use a tokenless (lexer-less) parsing approach.

- Works well with parser combinators;
- Good support by megaparsec.

Analysis: Tokenless parsing

Tokens are parsed using special `symbol` parsers.

```
-- ...

tTrue :: Parser T.Text
tTrue = symbol "true"

tFalse :: Parser T.Text
tFalse = symbol "false"

tEmptyList :: Parser T.Text
tEmptyList = symbol "[]"

-- ...
```

Analysis: Tokenless parsing

Token parsers strip whitespace (spaces, tabs, comments) at the end of the input:

```
whitespace = L.space
  space1
  (L.skipLineComment "//")
  (L.skipBlockComment "/*" "*/")

tColon :: Parser T.Text
tColon = symbol ":"

-- tColon parses ":", but also ": /* Parsers are fun */"
```

Analysis: Tokenless parsing

```
pProgram :: Parser Program
pProgram = L.whitespace *> some pDecl
```

Analysis: Generating expression parsers

```
operatorTable :: [[Operator Parser Expr]]
operatorTable =
  [ [ Postfix (UnaryOp (FieldAccess HeadField)
        <$ try (L.tDot <* L.tHead))
    , Postfix (UnaryOp (FieldAccess TailField)
        <$ try (L.tDot <* L.tTail))
    ]
  , ...
  ]

pTerm :: Parser Expr
pTerm = choice
  [ try $ L.parens pExpr
  , try pFunctionCall
  , try pAssignExpr
  , try pLiteralExpr
  , try pVariableExpr
  ]

pExpr :: Parser Expr
pExpr = makeExprParser pTerm operatorTable
```

Analysis: Testing the parser

```haskell
exprSpec :: Spec
exprSpec = do
  describe "Parser.Expr" $ do
    describe "pExpr" $ do
      it "parses a term" $ do
        parse pExpr "test.spl" "1"
          `shouldParse` LiteralExpr (IntLit 1)
        parse pExpr "test.spl" "a = 'b'"
          `shouldParse` AssignExpr (Identifier "a" Nothing) (LiteralExpr $ CharLit 'b')
        parse pExpr "test.spl" "ident"
          `shouldParse` VariableExpr (Identifier "ident" Nothing)
        parse pExpr "test.spl" "(a + b)"
          `shouldParse` BinOp Add
              (VariableExpr (Identifier "a" Nothing))
              (VariableExpr (Identifier "b" Nothing))
```

Analysis: Testing the parser

```
Parser.Expr
  pExpr
    parses a term [v]
    parses a simple unary expression [v]
    parses a simple binary expression [v]
    parses an expression [v]
```

Analysis: Testing the parser output

```
describe "pTrue" $ do
  it "parses the string 'true' as TrueLit" $ do
      parse pTrue "test.spl" "false" `shouldParse` TrueLit
```

Analysis: Testing the parser output

```
pTrue
  parses the string 'true' as TrueLit [x]

Failures:

  app/Test/Parser/Expr.hs:132:48:
  1) Parser.Parser.Parser.Expr.pTrue parses
    the string 'true' as TrueLit
      expected: TrueLit
      but parsing failed with error:
        test.spl:1:1:
          |
        1 | false
          | ^^^^
        unexpected "fals"
        expecting "true"
```

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Abstract syntax tree: design goals

- We started with the design of our AST, and based our parser on that;
- Tried to make the AST only be able to represent syntactically valid programs;
- Tried to make the AST as simple as possible;
- `data` type is Haskell.

Abstract syntax tree: The Skeleton

```
type Program = [Decl]
data Decl = ...
data Type = ...
data Stmt = ...
data Expr = ...
data UnaryOp = ...
data BinOp = ...
data Variable = ...
data Field = ...
data Literal = ...
```

Abstract syntax tree: example

```haskell
data Stmt =
  ReturnStmt (Maybe Expr)
| IfStmt Expr [Stmt] (Maybe [Stmt])
| WhileStmt Expr [Stmt]
| ExprStmt Expr
| VarStmt (Maybe Type) String Expr
deriving (Eq, Show)
```

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Error reporting

Megaparsec generates decent error messages out of the box:

```
examples/product_parse_error.spl:1:19:
  |
1 | product(list:[Int]: Int {
  |                   ^
unexpected ':'
expecting ')' or ','
```

But also has support for custom error messages, and even error recovery. We have not yet implemented this.

Side quest: A pretty printer

Pretty printer

```
fib(n : Int) : Int {
  if (n == 0) {return 0;}


if     (n == 1) {
  if            (true)            {print('h':'i':[]);}
return 1;}return (fib(n - 1) + fib(n - 2));  }
```

Pretty printer

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Pretty printer

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  if (n == 0) {
      return 0;
  }
  if (n == 1) {
      if (true) {
          print('h':'i':[]);
      }
      return 1;
  }
  return fib(n - 1) + fib(n - 2);

}
```

Pretty printer - Comments

```
fib(n : Int) : Int {
  if (n == 0) {return 0;}

/*    //| ________________
0|===|* >________________>
      \|                        */

if    (n == 1) { //                                    h   i
  if /* always true? */  (true) /* hi */    {print('h':'i':[]);}
return 1;}return (fib(n - 1) + fib(n - 2));  }
```

Pretty printer - Comments

```
fib(n : Int) : Int {
  if (n == 0) {
      return 0;
  }
  if (n == 1) {
      if (true) {
          print('h':'i':[]);
      }
      return 1;
  }
  return fib(n - 1) + fib(n - 2);

}
```

Pretty printer - Comments

```
type Program = ([Decl], [Comment])

                          -- start  end
data Comment = Single Int Int Int Int String
             | Multi  Int Int Int Int String
```

Pretty printer - Comments

```
type Program = ([Decl], [Comment])

                          -- start  end
data Comment = Single Int Int Int Int String
             | Multi  Int Int Int Int String
```

Make the symbol parser fix it.

Questions?