CSCI 334:
Principles of Programming Languages

Lecture 13: Parsing

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Topics

Parts of a language

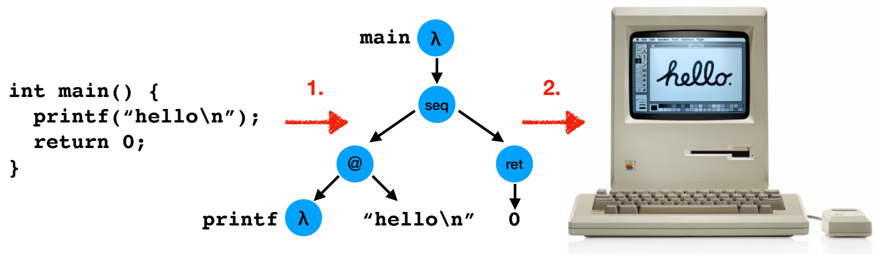
Parser combinators

Your to-dos

1. Read Parser Combinators for **next week**.
2. Lab 6, **due Sunday Oct 29** (solo lab).
3. Project **checkpoint #1**, due **Sunday, Nov 5**.

How do programs run?

How do programs run?



1. lexical analysis (“front-end”)
2. evaluation (“back-end”)

Front-end: the parser

A **parser** is a **function** that takes as input a string of symbols conforming to the rules of a formal grammar. If the string is not a valid sentence in the language, the parser **rejects** the string. If the string is a valid sentence in the language, the parser **accepts** the string and outputs a data structure that **represents the meaning of the sentence**.

For programming languages, meaning is generally represented in the form of an **abstract syntax tree** (AST). In an AST, conventionally, interior nodes are operations, and leaves are data.

Front-end: the parser

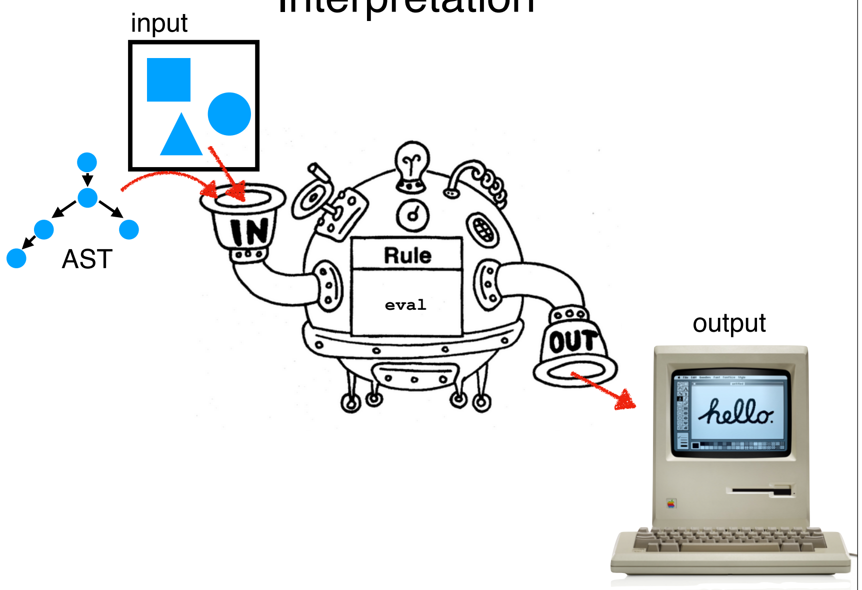
The subject of today’s lesson.

Back-end: the evaluator

There are two kinds of back-end:

1. Interpreter
2. Compiler

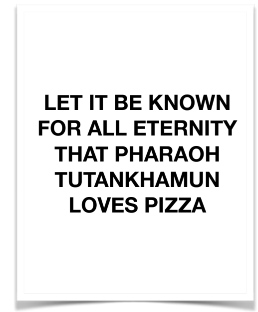
Interpretation



Interpretation Downsides

- Usually (very) slow

  (often 100-200x slower than compilation)



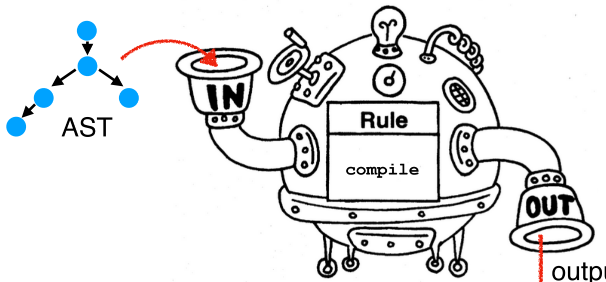
Interpretation Advantages

- An interpreter is “just a program” so debugging a language is the same as debugging any other program.

Some interpreted languages

- Most Lisps
- Python
- Ruby
- MATLAB
- R
- (sort of) Java and JavaScript

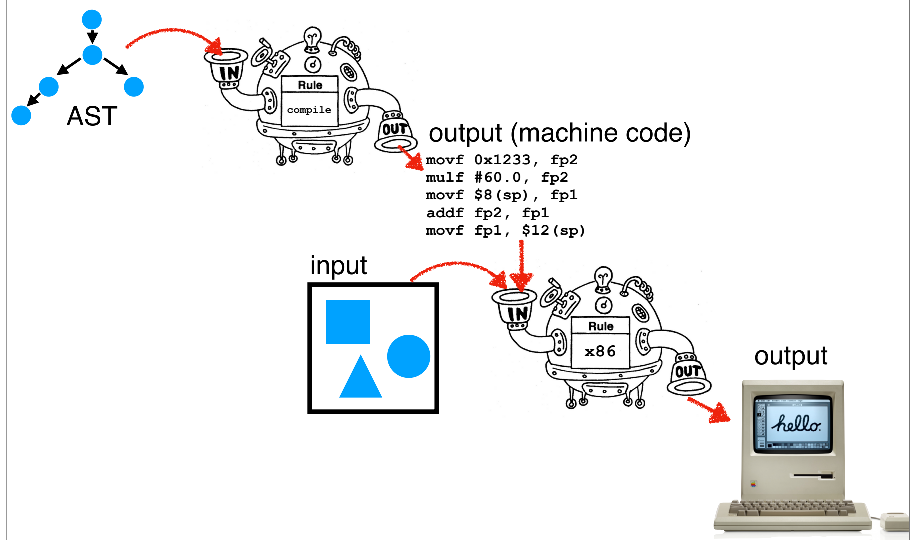
Compilation



output (machine code)

```
movf 0x1233, fp2
mulf #60.0, fp2
movf $8(sp), fp1
addf fp2, fp1
movf fp1, $12(sp)
```

Compilation

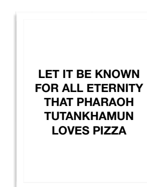


Some compiled languages

- C
- C++
- Go
- FORTRAN
- Java (sort of)
- C# (ditto)
- F# (ditto)

Compilation Advantages

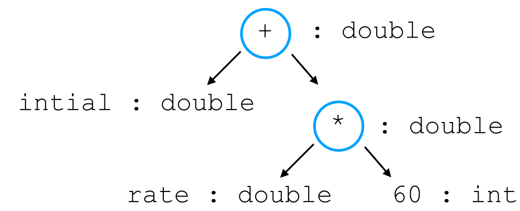
- Usually (very) fast
  (only 1.5-2X slower than hand-optimized assembly code)
- Compiled program is in machine (binary) format; difficult to debug the language itself.



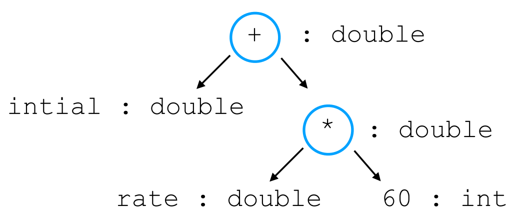
Compilation Example

Parsing

```
double position = initial + (rate * 60)
```



Intemediate Representation




```
temp1 = convert_int_to_double(60)
temp2 = mult(rate, temp1)
temp3 = add(initial, temp2)
position = temp3
```

"Optimization"

```
temp1 = convert_int_to_double(60)
temp2 = mult(rate, temp1)
temp3 = add(initial, temp2)
position = temp3
```

```
temp1 = mult(rate, 60.0)
position = add(initial, temp1)
```

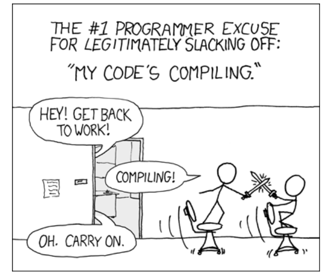
Instruction Selection

```
temp1 = mult(rate, 60.0)
position = add(initial, temp1)
```

```
movf rate, fp2
mulf #60.0, fp2
movf initial, fp1
addf fp2, fp1
movf fp1, position
```

Compilation Downsides

- Compilation can take a long time

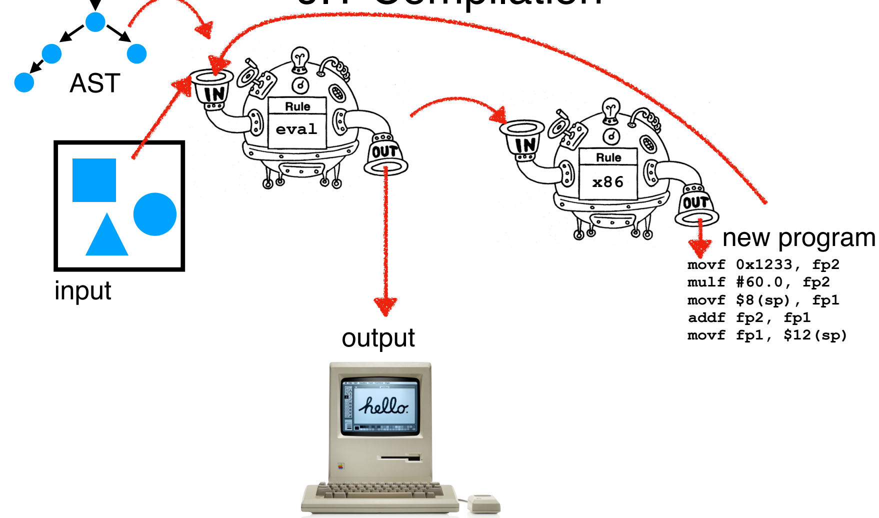


- Cannot modify program without source code.
- Hard to evolve language; compilers are complex.

Some hybrid (JIT) languages

- Java (C#, F#)
- JavaScript

JIT-Compilation



History

- Surprisingly, compilers were invented before interpreters.
- More obvious to early engineers.

Compilers: History

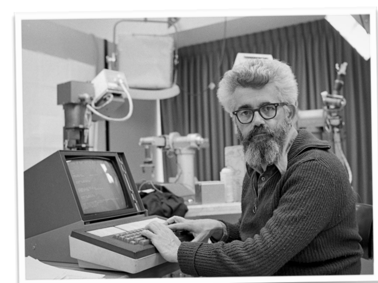
- Invented by Grace Hopper in 1952 while working on the A-0 and FLOW-MATIC languages.
- Work eventually became the COBOL programming language, still widely in use today.

Compilers: History

I used to be a mathematics professor. At that time I found there were a certain number of students who could not learn mathematics. I then was charged with the job of making it easy for businessmen to use our computers. I found it was not a question of whether they could learn mathematics or not, but whether they would. […] They said, 'Throw those symbols out — I do not know what they mean, I have not time to learn symbols.' I suggest a reply to those who would like data processing people to use mathematical symbols that they make them first attempt to teach those symbols to vice-presidents or a colonel or admiral. I assure you that I tried it. — Grace Hopper

Interpreters: History

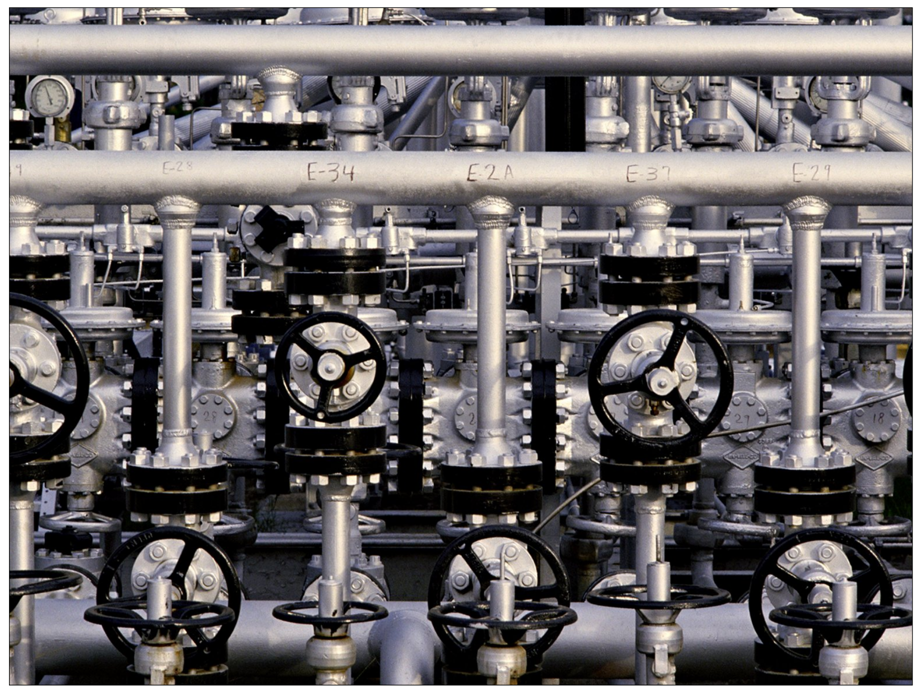
- Invented by John McCarthy in 1958 while working on LISP.
- Invented as a byproduct of McCarthy's thinking about computation from first principles.
- McCarthy wanted to build computers that could *think*!

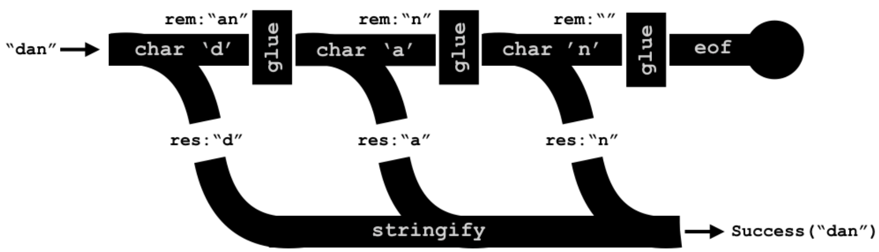


- LISP was too resource hungry for most uses at the time.

Parsers

Parser Combinators





Parser Combinators

- A kind of recursive decent parser.
- A **recursive descent parser** is a parser built from a set of **mutually recursive procedures** where each such procedure usually **implements one of the productions** of the grammar.
- Recursive descent parsers are "**top-down**," meaning that they recognize sentences by expanding nonterminals, starting from the start symbol.
- "**Bottom-up**" parsers start with *terminal* symbols and work in the opposite direction, often utilizing dynamic programming… these are more common in practice!

Basic Primitives

- Input

```
type Input = string * int * bool
```

- Output

```
type Outcome<'a> =
| Success of result: 'a * remaining: Input
| Failure of fail_pos: int * rule: String
```

Basic Primitives

- A parser is

```
type Parser<'a> = Input -> Outcome<'a>
```

- Keep in mind: a parser *is a function*.

Two varieties of parser

- Parsers that consume input. Correspond with grammar terminals.
- Parsers that combine parsers. Correspond with grammar non-terminals. Also called “combining forms.”
- For flexibility, you can also have parsers that do both.

A very simple terminal parser

- To parse a given char
  `pchar(c: char) : Parser<char>`
- Notice that the generic type inside `<brackets>` is the return type of the parser.
- So `pchar` returns a *parser*.
- When it is run with an *input*, it returns an `Outcome<char>`.

How to use it

- `(pchar ‘z’) input`
- `input` must be “prepared” first.
- `> let input = "zoo";;`
  `val input : string = “zoo"`
- `> let i = prepare input;;`
  `val i : Input = ("zoo", 0, false)`
- `> (pchar 'z') i;;`
  `val it : Outcome<char> = Success ('z',("oo", 1, false))`

A very simple combining parser

- To parse two things in sequence:
  `pseq : p1:Parser<‘a> -> p2:Parser<‘b> ->`
  `f:('a * 'b -> 'c) -> Parser<‘c>`
- It looks more complicated than it is.
- Let’s look at each part.

A very simple combining parser

- pseq :

```
p1:Parser<'a>
->
p2:Parser<'b>
->
f:('a * 'b -> 'c) -> Parser<'c>
```

- **p1** is a parser.

A very simple combining parser

- pseq :

```
p1:Parser<'a>
->
p2:Parser<'b>
->
f:('a * 'b -> 'c) -> Parser<'c>
```

- **p2** is a parser.

A very simple combining parser

- pseq :

```
p1:Parser<'a>
->
p2:Parser<'b>
->
f:('a * 'b -> 'c) -> Parser<'c>
```

- **f** is a function that takes the result of **p1** and **p2** and **does something** with it. That **something** is up to **you**.

How to use it

- `pseq (pchar 'z') (pchar 'o') id`
- `id` is F#'s identity function.
- Let's play with this in `fsharpi`.

More details

- It is **critical** that you read the "Parser Combinators" reading.
- I suggest that you **sit down, uninterrupted, for an hour or two**, and **work through the examples** in `fsharpi`.
- The reading builds the `Combinator.fs` library that you are given for HW7.

Recap & Next Class

Today:

Part of a language

Parser combinators

Next class:

Writing a parser