Announcements

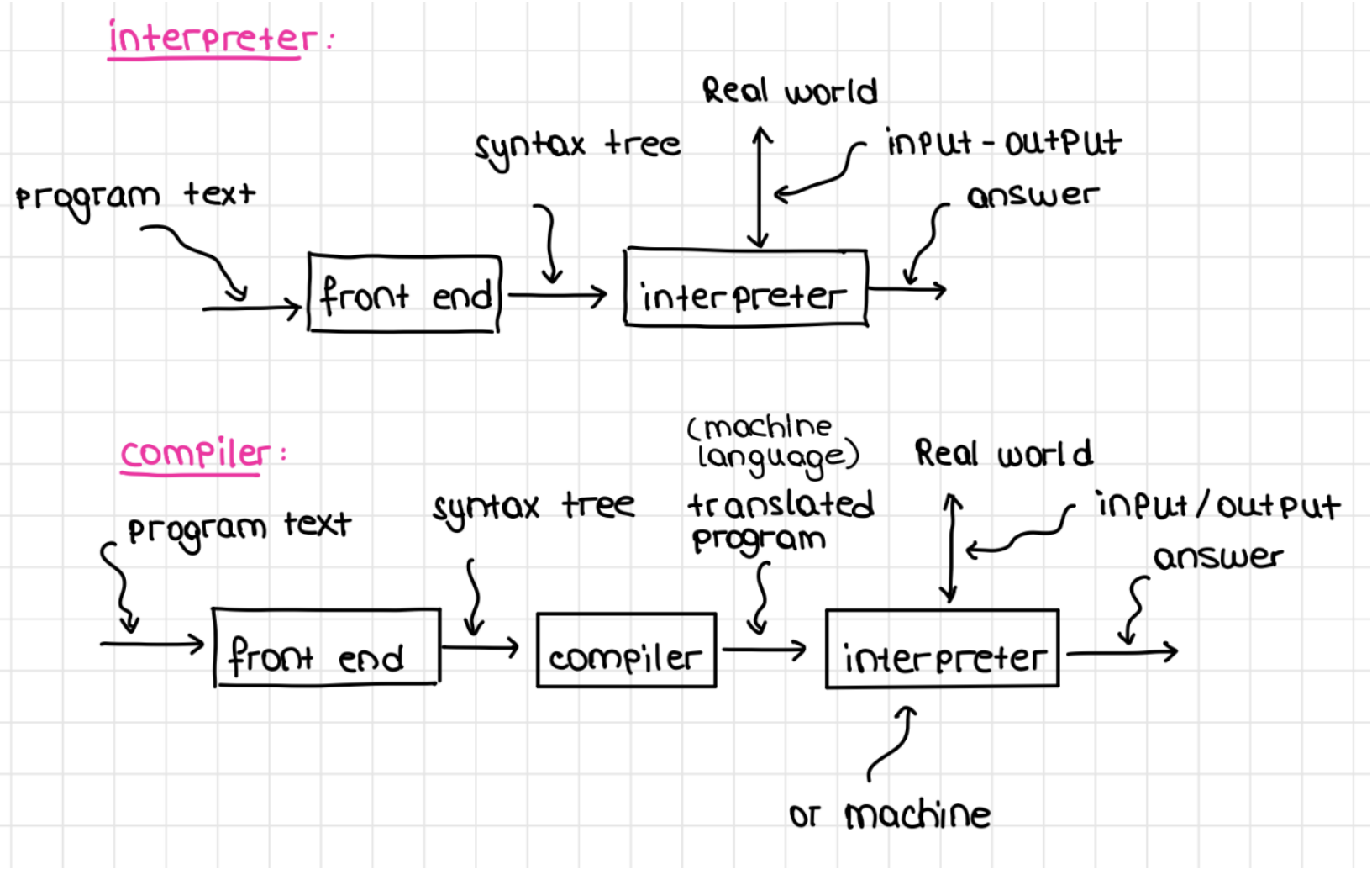
1. Lecture notes
2. Project coming
3. Midterm

COMP 301 01 PROGRAM. LANG. CONCEPTS Sunday, November 26, 2023 11:45:00 AM 2:45:00 PM SOSB07 MID TEVFİK SEZGİN
COMP 301 01 PROGRAM. LANG. CONCEPTS Sunday, November 26, 2023 11:45:00 AM 2:45:00 PM SOSB08 MID TEVFİK SEZGİN 11:30

Lecture 10
Abstract Syntax, Representation, Interpretation

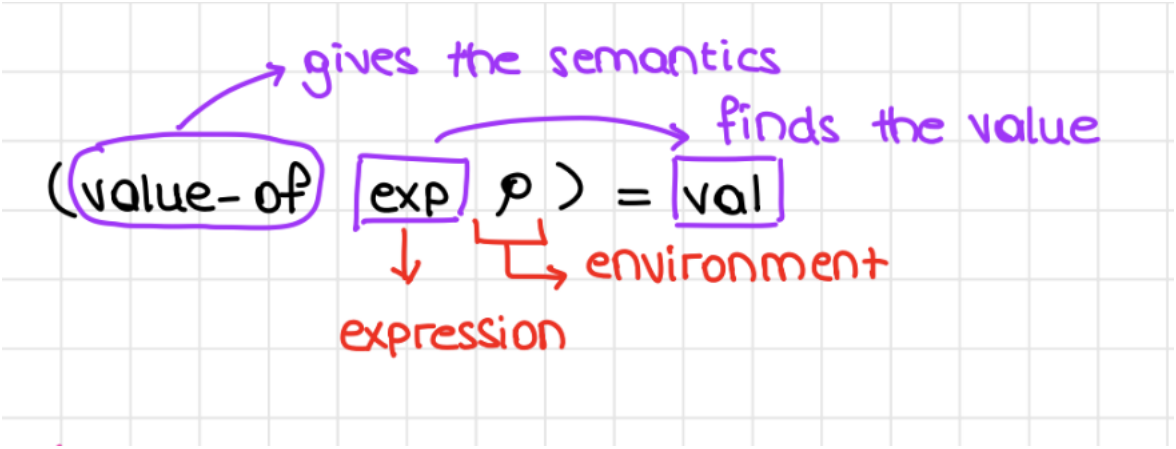
T. METIN SEZGIN

Interpreters and Compilers



Credit: Ceren Tarim

Evaluation



Credit: Ceren Tarim

LET Language:

grammar

Program ::= *Expression* → concrete syntax

`a-program (exp1)` → abstract syntax

Expression ::= *Number*

`const-exp (num)`

Expression ::= `-(` *Expression* `,` *Expression* `)`

`diff-exp (exp1 exp2)`

Expression ::= `zero?` `(` *Expression* `)`

`zero?-exp (exp1)`

Expression ::= `if` *Expression* `then` *Expression* `else` *Expression*

`if-exp (exp1 exp2 exp3)`

Expression ::= *Identifier*

`var-exp (var)`

x = 5 -(x,5)

Expression ::= `let` *Identifier* `=` *Expression* `in` *Expression*

`let-exp (var exp1 body)`

Credit: Ceren Tarim

Syntax data types:

Program ::= *Expression*
`a-program (exp1)`

Expression ::= *Number*
`const-exp (num)`

Expression ::= `-(`*Expression* `,` *Expression*`)`
`diff-exp (exp1 exp2)`

Expression ::= `zero? (`*Expression*`)`
`zero?-exp (exp1)`

Expression ::= `if` *Expression* `then` *Expression* `else` *Expression*
`if-exp (exp1 exp2 exp3)`

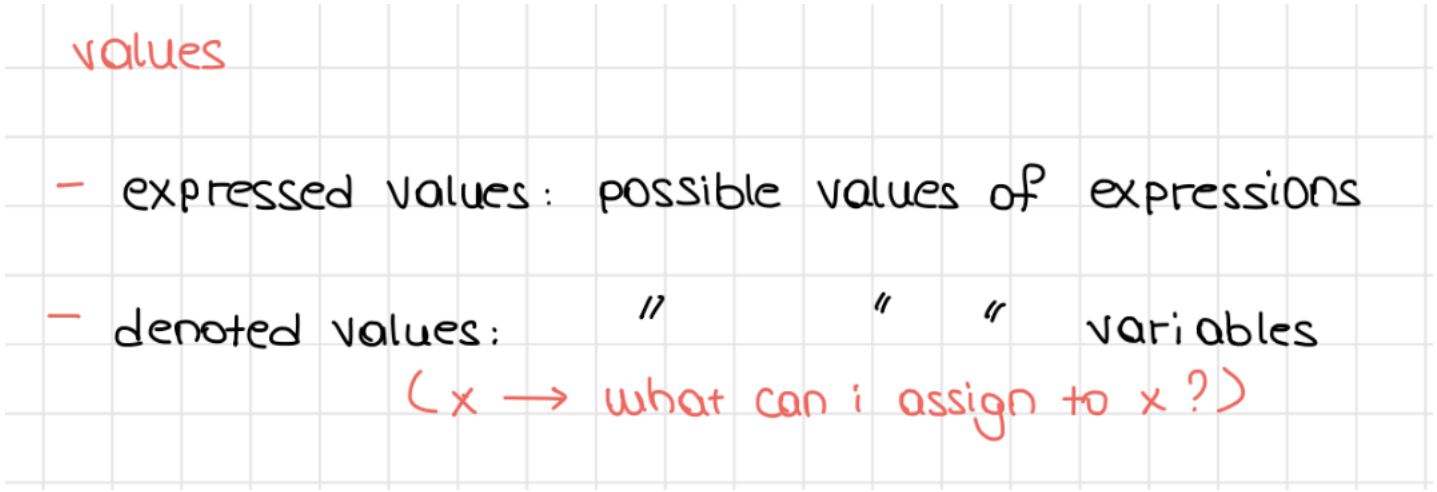
Expression ::= *Identifier*
`var-exp (var)`

Expression ::= `let` *Identifier* `=` *Expression* `in` *Expression*
`let-exp (var exp1 body)`

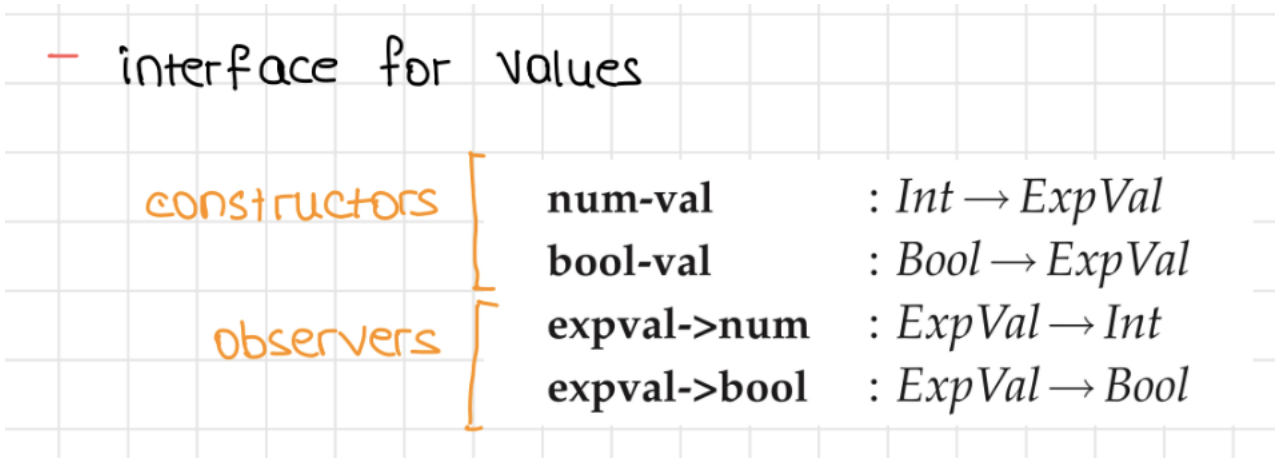
```
(define-datatype program program?
  (a-program
    (exp1 expression?)))

(define-datatype expression expression?
  (const-exp
    (num number?))
  (diff-exp
    (exp1 expression?)
    (exp2 expression?))
  (zero?-exp
    (exp1 expression?))
  (if-exp
    (exp1 expression?)
    (exp2 expression?)
    (exp3 expression?))
  (var-exp
    (var identifier?))
  (let-exp
    (var identifier?)
    (exp1 expression?)
    (body expression?)))
```

Credit: Ceren Tarim

Values



Credit: Ceren Tarim



Credit: Ceren Tarim

Specifying the behavior:

of expressions:

constructors:

const-exp	$: Int \rightarrow Exp$
zero?-exp	$: Exp \rightarrow Exp$
if-exp	$: Exp \times Exp \times Exp \rightarrow Exp$
diff-exp	$: Exp \times Exp \rightarrow Exp$
var-exp	$: Var \rightarrow Exp$
let-exp	$: Var \times Exp \times Exp \rightarrow Exp$

observer:

value-of $: Exp \times Env \rightarrow ExpVal$

↳ finding values of expressions

```
(value-of (const-exp n) ρ) = (num-val n)

(value-of (var-exp var) ρ) = (apply-env ρ var)

(value-of (diff-exp exp1 exp2) ρ)
= (num-val
    (-
      (expval->num (value-of exp1 ρ))
      (expval->num (value-of exp2 ρ))))
```

get the expval

converts expval to numeric value

of programs.

```
(value-of-program exp)
= (value-of exp [i=⌈1⌉,v=⌈5⌉,x=⌈10⌉])
```

default environment (initial)

Credit: Ceren Tarim

Lecture 11
Let

T. METIN SEZGIN

Nuggets of the lecture

- Let is a simple but expressive language
- Steps of inventing a language
- Values
- We specify the meaning of expressions first

Nugget

Let is a simple but expressive language

LET: our pet language

Program ::= *Expression*

```
a-program (exp1)
```

Expression ::= *Number*

```
const-exp (num)
```

Expression ::= `-(`*Expression* `,` *Expression*`)`

```
diff-exp (exp1 exp2)
```

Expression ::= `zero?` `(`*Expression*`)`

```
zero?-exp (exp1)
```

Expression ::= `if` *Expression* `then` *Expression* `else` *Expression*

```
if-exp (exp1 exp2 exp3)
```

Expression ::= *Identifier*

```
var-exp (var)
```

Expression ::= `let` *Identifier* `=` *Expression* `in` *Expression*

```
let-exp (var exp1 body)
```

An example program

- Input

```
"-(55, -(x,11))"
```

- Scanning & parsing

```
(scan&parse "-(55, -(x,11))")
```

- The AST

```
#(struct:a-program
   #(struct:diff-exp
      #(struct:const-exp 55)
      #(struct:diff-exp
         #(struct:var-exp x)
         #(struct:const-exp 11))))
```

Program ::= *Expression*
`a-program (exp1)`

Expression ::= *Number*
`const-exp (num)`

Expression ::= `-(`*Expression* `,` *Expression*`)`
`diff-exp (exp1 exp2)`

Expression ::= `zero?` `(`*Expression*`)`
`zero?-exp (exp1)`

Expression ::= `if` *Expression* `then` *Expression* `else` *Expression*
`if-exp (exp1 exp2 exp3)`

Expression ::= *Identifier*
`var-exp (var)`

Expression ::= `let` *Identifier* `=` *Expression* `in` *Expression*
`let-exp (var exp1 body)`

Nugget

Steps of inventing a language

Components of the language

- Syntax and datatypes
- Values
- Environment
- Behavior specification
- Behavior implementation
  - Scanning
  - Parsing
  - Evaluation

Nugget

We specify the meaning of expressions first

Specifying the behavior

- Programs

```
(value-of-program exp)
= (value-of exp [i=⌈1⌉,v=⌈5⌉,x=⌈10⌉])
```

- Expressions
  - Constructors

const-exp	$: Int \to Exp$
zero?-exp	$: Exp \to Exp$
if-exp	$: Exp \times Exp \times Exp \to Exp$
diff-exp	$: Exp \times Exp \to Exp$
var-exp	$: Var \to Exp$
let-exp	$: Var \times Exp \times Exp \to Exp$

```
(value-of (const-exp n) ρ) = (num-val n)
(value-of (var-exp var) ρ) = (apply-env ρ var)
```

```
(value-of (diff-exp exp1 exp2) ρ)
= (num-val
    (-
      (expval->num (value-of exp1 ρ))
      (expval->num (value-of exp2 ρ))))
```

  - Observer

value-of	$: Exp \times Env \to ExpVal$

Specifying the behavior

- Programs

```
(value-of-program exp)
= (value-of exp [i=1,v=5,x=10])
```

- Expressions
  - Constructors

const-exp	$: Int \to Exp$
zero?-exp	$: Exp \to Exp$
if-exp	$: Exp \times Exp \times Exp \to Exp$
diff-exp	$: Exp \times Exp \to Exp$
var-exp	$: Var \to Exp$
let-exp	$: Var \times Exp \times Exp \to Exp$

$$\frac{\texttt{(value-of } exp_1 \ \rho) = val_1}{\texttt{(value-of (zero?-exp } exp_1) \ \rho) = \begin{cases} \texttt{(bool-val \#t)} & \text{if } \texttt{(expval->num } val_1) = 0 \\ \texttt{(bool-val \#f)} & \text{if } \texttt{(expval->num } val_1) \neq 0 \end{cases}}$$

$$\frac{\texttt{(value-of } exp_1 \ \rho) = val_1}{\texttt{(value-of (if-exp } exp_1 \ exp_2 \ exp_3) \ \rho) = \begin{cases} \texttt{(value-of } exp_2 \ \rho) & \text{if } \texttt{(expval->bool } val_1) = \texttt{\#t} \\ \texttt{(value-of } exp_3 \ \rho) & \text{if } \texttt{(expval->bool } val_1) = \texttt{\#f} \end{cases}}$$

  - Observer

value-of	$: Exp \times Env \to ExpVal$

Specifying the behavior

- Programs

```
(value-of-program exp)
= (value-of exp [i=⌈1⌉,v=⌈5⌉,x=⌈10⌉])
```

- Expressions
  - Constructors

const-exp	$: Int \to Exp$
zero?-exp	$: Exp \to Exp$
if-exp	$: Exp \times Exp \times Exp \to Exp$
diff-exp	$: Exp \times Exp \to Exp$
var-exp	$: Var \to Exp$
let-exp	$: Var \times Exp \times Exp \to Exp$

$$\frac{\texttt{(value-of } exp_1 \ \rho) = val_1}{\texttt{(value-of (let-exp } var \ exp_1 \ body) \ \rho) = \texttt{(value-of } body \ [var = val_1]\rho)}$$

```
(value-of (let-exp var exp1 body) ρ)
= (value-of body [var=(value-of exp1 ρ)]ρ)
```

  - Observer

value-of	$: Exp \times Env \to ExpVal$

Behavior implementation

what we envision

Let ρ = [i=1,v=5,x=10].

```
(value-of
  <<-(-(x,3), -(v,i))>>
  ρ)

= ⌈(-
     ⌊(value-of <<-(x,3)>> ρ)⌋
     ⌊(value-of <<-(v,i)>> ρ)⌋)⌉

= ⌈(-
     (-
       ⌊(value-of <<x>> ρ)⌋
       ⌊(value-of <<3>> ρ)⌋)
     ⌊(value-of <<-(v,i)>> ρ)⌋)⌉

= ⌈(-
     (-
       10
       ⌊(value-of <<3>> ρ)⌋)
     (value-of <<-(v,i)>> ρ))⌉
```

```
= ⌈(-
     (-
       10
       3)
     ⌊(value-of <<-(v,i)>> ρ)⌋)⌉

= ⌈(-
     7
     ⌊(value-of <<-(v,i)>> ρ)⌋)⌉

= ⌈(-
     7
     (-
       ⌊(value-of <<v>> ρ)⌋
       ⌊(value-of <<i>> ρ)⌋))⌉

= ⌈(-
     7
     (-
       5
       ⌊(value-of <<i>> ρ)⌋))⌉
```

```
= ⌈(-
     7
     (-
       5
       1))⌉

= ⌈(-
     7
     4)⌉

= ⌈3⌉
```