COSE212: Programming Languages

Lecture 9 — Automatic Type Inference (1)

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#### Type Inference?

- $(\operatorname{proc}(x) x) 1$ :
- proc (x) (x 1):
- proc(x)(proc(y)x):

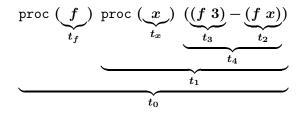
#### Automatic Type Inference

- A static analysis that automatically figures out types of expressions by observing how they are used.
- The analysis can always infer the types of any expression, for a carefully designed language.
  - ▶ If an expression has a type according to the type system, the analysis is guaranteed to find the type.
  - If the analysis finds a type for an expression, the expression is well-typed with they type according to the type system.
- The analysis consists of two steps:
  - Generate type equations from the program.
  - Solve the equations.

#### Generating Type Equations

For every subexpression and every variable,

• introduce type variables, and ex) proc (f) proc (x) ((f 3) - (f x)):



• derive equations between the variables.

### Deriving Equations from Typing Rules

$$egin{array}{ccc} \Gamma dash E_1: \mathsf{int} & \Gamma dash E_2: \mathsf{int} \ \hline \Gamma dash E_1 + E_2: \mathsf{int} \end{array}$$

$$t_{E_1} = \operatorname{int} \ \wedge \ t_{E_2} = \operatorname{int} \ \wedge \ t_{E_1 + E_2} = \operatorname{int}$$

$$\Gamma \vdash E : \mathsf{int}$$
 $\Gamma \vdash \mathsf{zero}? \ E : \mathsf{bool}$ 

$$t_E = \mathsf{int} \ \land \ t_{(\mathsf{zero?}\ E)} = \mathsf{bool}$$

$$egin{array}{lcl} t_{E_1} & = & \mathsf{bool} \wedge \ t_{E_2} & = & t_{(\mathsf{if} \ E_1 \ \mathsf{then} \ E_2 \ \mathsf{else} \ E_3)} \wedge \ t_{E_3} & = & t_{(\mathsf{if} \ E_1 \ \mathsf{then} \ E_2 \ \mathsf{else} \ E_3)} \end{array}$$

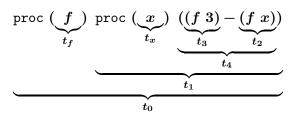
## Deriving Equations from Typing Rules

$$egin{aligned} rac{\Gamma dash E_1:t_1 o t_2 \qquad \Gammadash E_2:t_1}{\Gammadash E_1\ E_2:t_2} \ & t_{E_1}=t_{E_2} o\ t_{(E_1\ E_2)} \end{aligned}$$

$$\frac{[x \mapsto t_1]\Gamma \vdash E: t_2}{\Gamma \vdash \operatorname{proc} x \ E: t_1 \to t_2}$$

$$t_{(\text{proc }(x)\ E)} = t_x \rightarrow t_E$$

$$\bullet \frac{\Gamma \vdash E_1:t_1 \qquad [x \mapsto t_1]\Gamma \vdash E_2:t_2}{\Gamma \vdash \mathsf{let}\ x = E_1\ \mathsf{in}\ E_2:t_2}$$



$$\mathtt{proc}\;(f)\;(f\;11)$$

if 
$$x$$
 then  $(x-1)$  else  $0$ 

$$\mathtt{proc}\;(f)\;(\mathtt{zero?}\;(f\;f))$$