COSE212: Programming Languages

Lecture 10 — Automatic Type Inference (1)

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Type Inference?

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

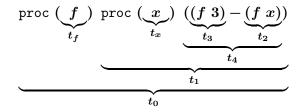
Automatic Type Inference

- 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

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

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

$$\Gamma \vdash E : \mathsf{int}$$
 $\Gamma \vdash \mathsf{iszero}\ E : \mathsf{bool}$

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

$$ullet rac{\Gamma dash E_1 : \mathsf{bool} \qquad \Gamma dash E_2 : t \qquad \Gamma dash E_3 : t}{\mathsf{if} \ E_1 \ \mathsf{then} \ E_2 \ \mathsf{else} \ E_3 : t}$$

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

Deriving Equations from Typing Rules

$$\bullet \frac{\Gamma \vdash E_1: t_1 \rightarrow t_2 \quad \Gamma \vdash E_2: t_1}{\Gamma \vdash E_1 \ E_2: t_2}$$

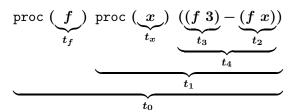
$$t_{E_1} = t_{E_2} \rightarrow t_{(E_1 E_2)}$$

$$[x\mapsto t_1]\Gamma dash E:t_2 \ \Gamma dash \operatorname{proc} x\ E:t_1 o t_2$$

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

$$egin{array}{ccc} \Gamma dash E_1:t_1 & [x \mapsto t_1]\Gamma dash E_2:t_2 \ \hline \Gamma dash ext{let } x = E_1 ext{ in } E_2:t_2 \end{array}$$

$$t_x = t_{E_1} \ \land \ t_{E_2} = t_{(\text{let } x = E_1 \ \text{in } E_2)}$$



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

if x then (x-1) else 0

$$\operatorname{proc}\ (f)\ (\operatorname{iszero}\ (f\ f))$$