Assignment-5

19CS10060

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1. • A <u>type error</u> occurs where a computational entity such as a function or a data value, is used in a manner that is inconsistent with the concept it represents.

• A <u>type system</u> is a ~~tractable~~ syntactic method for proving the absence of a certain program behaviours by classifying pharases according to the kinds of value they compute.

• <u>Advantage of type systems</u>:

(a) <u>Detecting errors</u>: Static type-checking allow early detection of some programming errors.

(b) <u>Abstraction</u>: Enforce disciplined programming.

(c) <u>Documentation</u>: Types are useful whil reading programs

(d) <u>Language safety</u>: A safe laguage protects its own abstraction, portability.

(e) <u>Efficiency</u>: Distinguish between integer-valued arithmatic expression and real valued one; Eliminate many of dynamic checks, etc.

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② • Type Inference is the process of determining the type of expressions based on the known types of some symbols that appear in them.

• Example by Hand-weaving:

let's : $f\ x = 2 + x$

$\gg f :: Int \rightarrow Int$

Type of f:

$+$ has type : $Int \rightarrow Int \rightarrow Int$

2 has type : Int

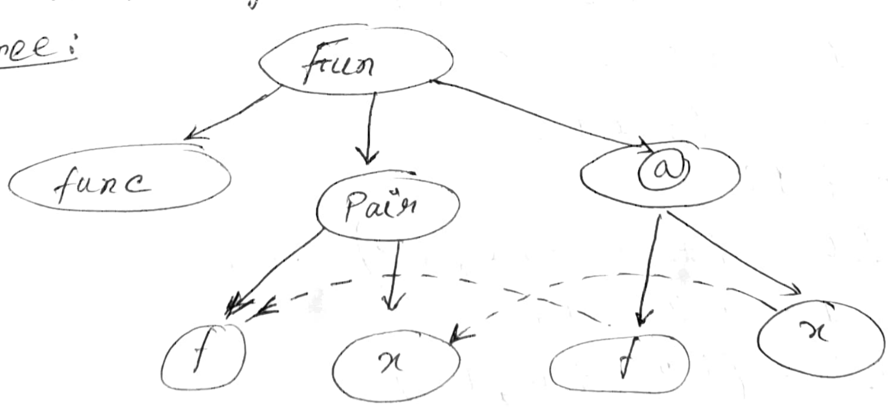
As we are applying $+$ to x we need $x :: Int$

$\Rightarrow f\ x = 2 + x$ has type $Int \rightarrow Int$.

• Type Inference Algo for polymorphic function:

$func\ (f, x) = f\ x$

Parse tree:



Assigning type variables to nodes of the parse tree and add the constraints:

$t\_1 = t\_2 \rightarrow t\_6$

$t\_0 = t\_3 \rightarrow t\_6$

$t\_3 = (t\_1, t\_2)$

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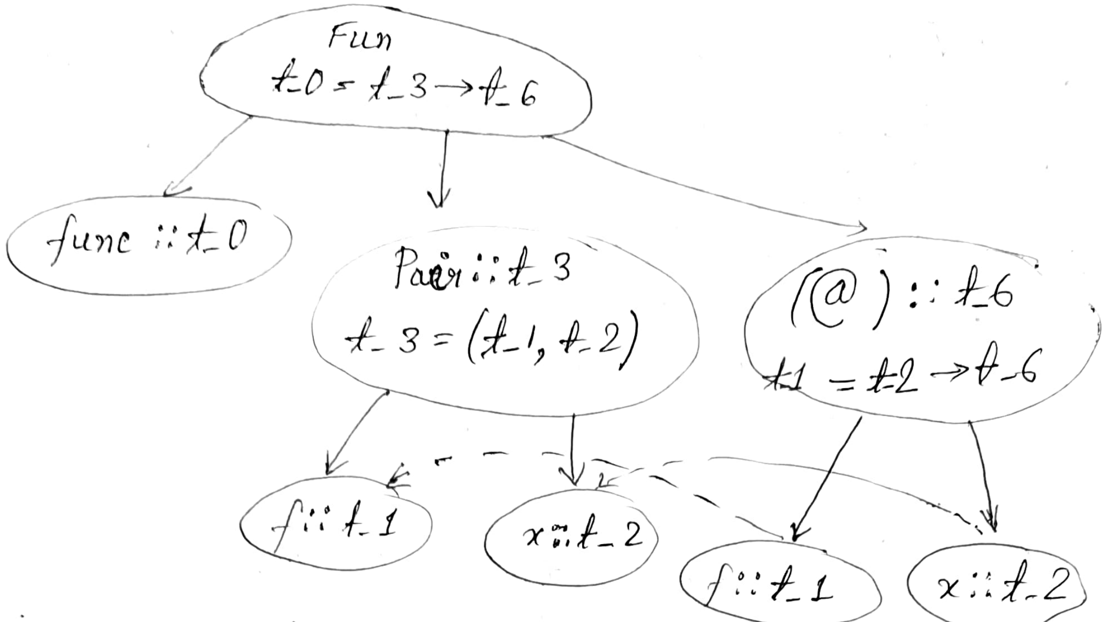

Solving constraints:

$t\_0 = t\_3 \rightarrow t\_6$

$t\_1 = t\_2 \rightarrow t\_6$

$t\_3 = (t\_1, t\_2)$

Replace t_3:

$t\_0 = (t\_1, t\_2) \rightarrow t\_6$

$t\_1 = t\_2 \rightarrow t\_6$

$t\_3 = (t\_1, t\_2)$

Replace t_1:

$t\_0 = (t\_2 \rightarrow t\_6, t\_2) \rightarrow t\_6$

$t\_1 = t\_2 \rightarrow t\_6$

$t\_3 = (t\_2 \rightarrow t\_6, t\_2)$

Replace t_2 with t and t_6 with t1:

$t\_0 = (t \rightarrow t1, t) \rightarrow t1$

$t\_1 = t \rightarrow t1$

$t\_3 = (t \rightarrow t1, t)$

Determining type:

func (f, x) = f x

> func :: (t -> t1, t) -> t1

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(3) • Type Inference Algorithm :

⇒ Assign type to the expression and subexpression.

- for any compound expression or any variable use a type variable
- For known operations or constants, such as + or 3, use the type that is known for this symbol.

⇒ Generate a set of constraints on types, using the parse tree of the expression. These constraints reflect the fact that if a function is applied to an argument, for example, then the type of the argument must equal the type of the domain of the function.

⇒ Solve these constraints by means of unification, it is a substitution-based algorithm for solving systems of equations.

• Framing and Solving Type Constraints (using a Matrix)

Find type of $(AB+C)^2$ given

$A : s \to t$

$B : u \to v$

$C : w \to x$.

Let us consider the type of a $m \times n$ matrix as $m \to n$.

Assigning type variable for the subexpressions of $(AB+C)^2$

$A : s \to t$	$AB : a \to b$
$B : u \to v$	$AB+C : c \to d$
$C : w \to x$	$(AB+C) : e \to f$

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Applying typing rules:

$t = u$, $a = s$, $b = v$ for AB

$a = c = w$, $b = d = x$ for $AB + C$

$c = d = e = f$ for $(AB+C)^2$

Typing rules used are:

Multiplication: $$\frac{E \vdash A : s \to t, \quad E \vdash B : t \to u}{E \vdash AB : s \to u}$$

Addition: $$\frac{E \vdash A : s \to t, \quad E \vdash B : s \to t}{E \vdash A+B : s \to t}$$

Squaring: $$\frac{E \vdash A : s \to s}{E \vdash A^2 : s \to s}$$

Solving the constraints, we get the following two equivalent classes,

$t = u$

$a = s = c = w = d = e = f = b = x = v$

Hence,

$A : a \to t$

$B : t \to a$

$C : a \to a$

is the most general typing

Any value of a, t make the expression $(AB+C)$ well formed.

4. Overload Resolution with One Parameter:

In the context of a list of function prototype:

```
int g(double);              // F1
void f();                   // F2
double h(void);             // F3
void f(int);                // F4
int g(char, int);           // F5
void f(double, double = 3.4);   // F6
void h(int, double);        // F7
void f(char, char*);        // F8
```

The call site to resolve is:

`f(5.6)`

Resolution

- Candidate functions (by name):
  F2, F4, F6, F8
- Viable functions are:
  F4, F6
- Best viable function: F6 (by type double - exact match)

⑤ Parametric Polymorphism:

refers to the ability where a function may be applied to any arguments whose types match a type expression involving type variables. Basically, it opens a way to use the same code for different types.

- In explicit parametric polymorphism, the program text contains type varitables that determine the way that a fuction or other value maybe treated polymorphically.

It often involves explicit instatiation or type application to indicate how type variable are replaced

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with specific types in the use of a polymorphic value. Examples include C++ templates.

- Implicit Parametric Polymorphism, also known as Haskell polymorphism deals with programs that declare and use polymorphic functions ~~that~~ but do not need to contain types. — the type-inference algorith computes when a function is polymorphic, and computes the instantiation of type variables as needed.

- rvalue reference:

For any type X, X&& is called an rvalue reference to x.

An rvalue reference behaves just like an lvalue references except that it can bind to a temporary (an rvalue), whereas lvalue reference cannot be bound to a rvalue.

It allow programmers to avoid logically unneccesary copying and provide perfect forwarding functions.

E.g.

```
void func(X& x); // lvalue reference
void func(X&& x); // rvalue reference
                  overload

X x;
X foobar();
func(x); // argument is lvalue, calls func(X&)
func(foobar()) // argument is rvalue, calls
                  func(X&&)
```