

# Type inference

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(adapted from John Mitchell's notes)

## Outline of lecture

- Why do we need type inference
  - Save programmer effort
  - More polymorphism
  - Find bugs
- A simple algorithm for type inference
- Reading: Mitchell, Section 5.4

## Saving programmer effort and program clutter

- `fun find (nil, _) = false`  
| `find (hd::tl, tofind) = tofind = hd orelse find(tl, tofind)`
- **OR**
- `fun find(nil: "a list, tofind: "a) = false`  
| `find((hd:"a)::(tl:"a list), tofind: "a) = tofind = hd orelse find(tl, tofind)`
- **This still doesn't include return types**
- **Counter argument: user types are useful documentation.** What do you think?

## Getting most general type

- Let's suppose I have lists of integers and I need a function that checks if an integer is in my list
  - `fun find(nil: int list, tofind: int) = false`  
| `find((hd:int)::(tl:int list), tofind: int) = tofind = hd or else find(tl, tofind)`
- Works for me but not too reusable

## Getting most general type (cont.)

- `fun add_to_list(alist, toadd) =  
 if find(alist, toadd) then alist else toadd::alist`
- Possible typing:  
`fun add_to_list(alist: 'a list, toadd: 'a) =  
 if find(alist, toadd) then alist else toadd::alist`
- Is this right?
- Polymorphic types are hard to manually get "right".

## Finding bugs

- `fun reverse (nil) = nil  
 | reverse(x::lst) = reverse(list);  
reverse: 'a list -> 'b list`
- The type doesn't look right. What is wrong?

## Summary of goals for type inference

- Give programmer the benefit of static typing without the effort
- Compute the most general type for functions to get maximum reusability
- Compute poor man's version of program "semantics"--useful for finding bugs

## SML type inference example

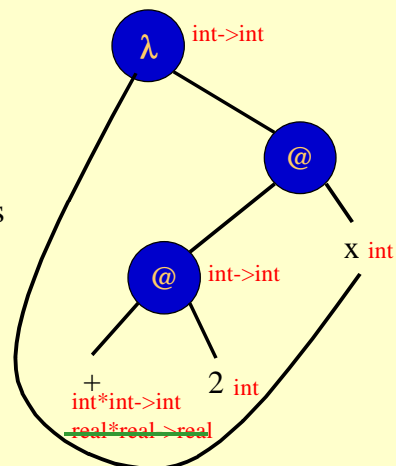
- Example
  - `fun f(x) = 2 + x;`
  - `f = fn: int->int`
- How does this work?
  - `+` has two types: `int*int->int`, `real*real->real`
  - `2: int` has only one type
  - Thus `+`: `int*int->int`
  - From context, need `x: int`
  - Therefore `f(x:int) = 2 + x` has type `int->int`

## SML type inference: another example

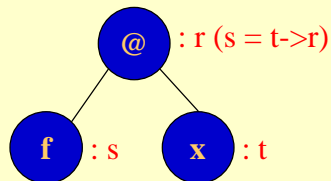
- `fun f(x) = x + x`
- What is the type of `f`?

## Another presentation

- Example
  - `fun f(x) = 2 + x;`
  - `f = fn : int->int`
- How does this work?
  - Assign types to leaves
  - Propagate to internal nodes and generate constraints
  - Solve by substitution

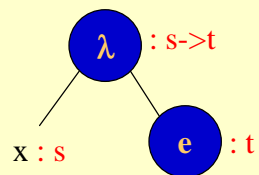


## Generating constraints



### Application:

- **f** must have function type **domain**->**range**
- domain of **f** must be type of argument **x**
- result type is range of **f**



### Function expression:

- Type is function type **domain**->**range**
- Domain is type of variable **x**
- Range is type of function body **e**

## Solving constraints

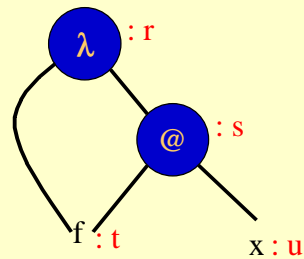
- **Unification**
- Basic idea:
  - If a constraint says  $t = u$ , **t** and **u** are type expressions, then unify values of **t** and **u**
  - If **t** or **u** is a primitive type then it is easy
  - If **t** and **u** are non-primitive types, then unify their components
  - If **t** is a type variable, replace uses of **t** with **u** (and vice versa)

## Solving constraints: examples

- $x = \text{int} \Rightarrow$   
 $x = \text{int}$
- $\text{int} \rightarrow 'a = 'b \rightarrow 'b \Rightarrow$   
 $\text{int} = 'b$  and  $'a = 'b \Rightarrow$   
 $\text{int} = 'a$
- $\text{int} * \text{bool} = 'a * 'a \Rightarrow$   
 $'a = \text{int}$  and  $'a = \text{bool} \Rightarrow$   
 $\text{int} = \text{bool}$   
Type error!

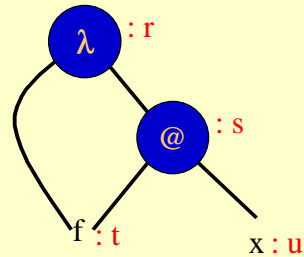
## Inferring polymorphic types

- Example
  - `fun apply(f, x) = f(x);`
  - `f = fn : ('a->'b) * 'a -> 'b`
- How does this work
  - Assign types to leaves
  - **Assign types to interior nodes**
  - Generate constraints
  - Unify!



## Example (cont.)

- Constraints:
  - $t = t1 \rightarrow t2$
  - $t1 = u$
  - $t2 = s$
  - $r = t * u \rightarrow s$
- Substituting for t
  - $t1 = u$
  - $t2 = s$
  - $r = (t1 \rightarrow t2) * u \rightarrow s$
- Substitute u for t1 and s for t2
  - $r = (u \rightarrow s) * u \rightarrow s$



## More on type inference

- Perfect type inference is undecidable
- SML type inference is exponential but seems to work
  - Programmer needs to intervene sometimes when overloaded functions are involved but otherwise it is mostly automatic

## Discussion

- Is type inference a good idea?
  - Does writing down types force programmers to think?
  - Is it easier to read, write, and debug programs without types?

## Next topic

- Using rich type systems to analyze programs
- Reading: (TBA)