

CSE505: Graduate Programming Languages

Lecture 20 — Bounded Polymorphism

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Winter 2012

Revenge of Type Variables

Sorted lists in ML (partial):

```
type 'a slist
make : ('a -> 'a -> int) -> 'a slist
cons : 'a slist -> 'a -> 'a slist
find : 'a slist -> 'a -> 'a option
```

Getting by with OOP subtyping:

```
interface Cmp { Int f(Object, Object); }
class SList {
  ... some field definitions ...
  constructor (Cmp x) {...}
  Slist cons(Object x) {...}
  Object find(Object x) {...}
}
```

Wanting Type Variables

Will downcast (potential run-time exception) the arguments to `f` and the result of `find`

We are not enforcing list-element type-equality

OOP-style subtyping is no replacement for parametric polymorphism; we can have both:

```
interface Cmp<'a> { Int f('a,'a); } // Cmp not a type
```

```
class SList<'a> { // SList not a type (SList<Int> e.g. is)
  ... some field definitions (can use type 'a) ...
```

```
  constructor (Cmp<'a> x) {...}
  Slist<'a> cons('a x)    {...}
  'a      find('a x)    {...}
}
```

Same Old Story

- ▶ Interface and class declarations are *parameterized*; they produce types
- ▶ The constructor is polymorphic
 - ▶ For all T, given a Cmp<T>, it makes a SList<T>
- ▶ If o has type SList<T>, its cons method:
 - ▶ Takes a T
 - ▶ Returns a SList<T>

No more downcasts; the best of both worlds

Complications

“Interesting” interaction with overloading and multimethods

```
class B {  
  unit f(C<Int> x) {...}  
  unit f(C<String> x) {...}  
}  
class C<'a> { unit g(B x) { x.f(self); } }
```

For $C<T>$ where T is neither `Int` nor `String`, can have no match

- ▶ Cannot resolve static overloading at compile-time without code duplication and no abstraction (C++)
- ▶ To resolve overloading or multimethods at run-time, need run-time type information *including the instantiation* T (C#)
- ▶ Could disallow such overloading (Java)
- ▶ Or could just reject this sort of call as unresolvable (?)

Wanting bounds

There are compelling reasons to *bound* the instantiation of type variables

Simple example: Use at supertype without losing that it's a subtype

```
interface I { unit print(); }
class Logger< 'a <: I > { // must apply to subtype of I
  'a item;
  'a get_it() { syslog(item.print()); item }
}
```

Without polymorphism or downcasting, client could only use `get_it` result for printing

Without bound or downcasting, `Logger` could not print

Issue isn't special to OOP

Fancy Example from “A Theory of Objects” Abadi/Cardelli

With forethought, bounds can avoid some subtyping limitations

```
interface Omnivore { unit eat(Food); }  
interface Herbivore { unit eat(Veg); } // Veg <= Food
```

Allowing $\text{Herbivore} \leq \text{Omnivore}$ could make a vegetarian eat meat (unsound)! But this works:

```
interface Omnivore< 'a <: Food > { unit eat('a); }  
interface Herbivore< 'a <: Veg > { unit eat('a); }
```

If $\text{Herbivore}\langle T \rangle$ is legal, then $\text{Omnivore}\langle T \rangle$ is legal *and*
 $\text{Herbivore}\langle T \rangle \leq \text{Omnivore}\langle T \rangle$!

Useful for unit `feed('a food, Omnivore<'a> animal) {...}`

Bounded Polymorphism

This “bounded polymorphism” is useful in any language with universal types and subtyping. Instead of $\forall\alpha.\tau$ and $\Lambda\alpha.e$, we have $\forall\alpha < \tau'.\tau$ and $\Lambda\alpha < \tau'.e$:

- ▶ Change Δ to be a list of bounds ($\alpha < \tau$) instead of a set of type variables
- ▶ In e you can subsume from α to τ'
- ▶ $e_1[\tau_1]$ typechecks when τ_1 “satisfies the bound” in type of e_1

One limitation: When is $(\forall\alpha_1 < \tau_1.\tau_2) \leq (\forall\alpha_2 < \tau_3.\tau_4)$?

- ▶ Contravariant bounds and covariant bodies assuming bound are sound, but makes subtyping undecidable
- ▶ Requiring invariant bounds and covariant bodies regains decidability, but obviously allows less subtyping