



#### CSE341: Programming Languages

## Lecture 25 Subtyping for OOP; Comparing/Combining Generics and Subtyping

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Objects: mostly records holding fields and methods

- Methods are immutable functions that also have access to

 Overriding methods could have contravariant arguments and covariant results compared to method overridden
 Sound only because method "slots" are immutable!

So could design a type system using types very much like

- Subtypes could have extra fields and methods

#### Now...

Use what we learned about subtyping for records and functions to understand subtyping for class-based OOP – Like in Java/C#
<ul> <li>Recall:</li> <li>Class names are also types</li> <li>Subclasses are also subtypes</li> <li>Substitution principle: Instance of subclass should usable in place of instance of superclass</li> </ul>
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<b>Actual Java/C#…</b> Compare/contrast to what our "theory" allows:
1. Types are class names and subtyping are explicit subclasses
2. A subclass can add fields and methods
<ol> <li>A subclass can override a method with a covariant return type</li> <li>(No contravariant arguments; instead makes it a non- overriding method of the same name)</li> </ol>
(1) Is a subset of what is sound (so also sound)
(3) Is a subset of what is sound and a different choice (adding method instead of overriding)

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## Classes vs. Types

An object is...

self

record types

- Fields are mutable

- A class defines an object's behavior
   Subclassing inherits behavior and changes it via extension and overriding
- A type describes an object's methods' argument/result types
   A subtype is substitutable in terms of its field/method types
- These are separate concepts: try to use the terms correctly
  - Java/C# confuse them by requiring subclasses to be subtypes
  - A class name is both a class and a type
  - Confusion is convenient in practice

# **Optional:** More details

Java and C# are sound: They do not allow subtypes to do things that would lead to "method missing" or accessing a field at the wrong type

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Confusing (?) Java example:

- Subclass can declare field name already declared by superclass
- Two classes can use any two types for the field name
- Instance of subclass have two fields with same name
- "Which field is in scope" depends on which class defined the method

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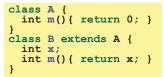
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#### self/this is special

- · Recall our Racket encoding of OOP-style
  - "Objects" have a list of fields and a list of functions that take self as an explicit extra argument
- So if self/this is a function argument, is it contravariant?
  - No, it is covariant: a method in a subclass can use fields and methods only available in the subclass: essential for OOP



- Sound because calls always use the "whole object" for self
- This is why coding up your own objects manually works much less well in a statically typed languages

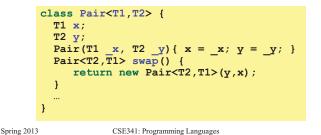
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#### Generics in Java

- Java generics a bit clumsier syntactically and semantically, but can express the same ideas
  - Without closures, often need to use (one-method) objects
  - See also earlier optional lecture on closures in Java/C
  - Simple example without higher-order functions (optional):



## What is subtyping good for?

Some good uses for subtype polymorphism:

- Code that "needs a Foo" but fine to have "more than a Foo"
- Geometry on points works fine for colored points
- GUI widgets specialize the basic idea of "being on the screen" and "responding to user actions"

#### What are generics good for?

Some good uses for parametric polymorphism:

· Types for functions that combine other functions:

fun compose  $(q,h) = fn x \Rightarrow q (h x)$ (\* compose : ('b -> 'c) \* ('a -> 'b) -> ('a -> 'c) \*)

Types for functions that operate over generic collections

```
val length : 'a list -> int
val map : ('a -> 'b) -> 'a list -> 'b list
val swap : ('a * 'b) -> ('b * 'a)
```

- · Many other idioms
- · General point: When types can "be anything" but multiple things need to be "the same type" CSE341: Programming Languages

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## Subtyping is not good for this

- Using subtyping for containers is much more painful for clients
  - Have to downcast items retrieved from containers
  - Downcasting has run-time cost
  - Downcasting can fail: no static check that container holds the type of data you expect
  - (Only gets more painful with higher-order functions like map)

```
class LamePair {
     Object x;
     Object y;
     LamePair(Object _x, Object _y) { x=_x; y=_y; }
     LamePair swap() { return new LamePair(y,x); }
   // error caught only at run-time:
   String s = (String) (new LamePair("hi",4).y);
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```

#### Awkward in MI

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ML does not have subtyping, so this simply does not type-check:

```
(* {x:real, y:real} -> real *)
fun distToOrigin ({x=x,y=y}) =
   Math.sqrt(x*x + y*y)
val five = distToOrigin {x=3.0,y=4.0,color="red"}
```

Cumbersome workaround: have caller pass in getter functions:

```
(* ('a -> real) * ('a -> real) * 'a -> real *)
fun distToOrigin (getx, gety, v) =
  Math.sqrt((getx v)*(getx v)
             + (gety v) * (gety v))
```

- And clients still need different getters for points, color-points

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#### Wanting both Example Method that takes a list of points and a circle (center point, radius) Could a language have generics and subtyping? - Return new list of points in argument list that lie within circle – Sure! Basic method signature: More interestingly, want to combine them List<Point> inCircle(List<Point> pts, "Any type T1 that is a subtype of T2" Point center, Called bounded polymorphism double r) { ... - Lets you do things naturally you cannot do with generics or Java implementation straightforward assuming Point has a subtyping separately distance method: List<Point> result = new ArrayList<Point>(); for(Point pt : pts) if(pt.distance(center) < r)</pre> result.add(pt); return result; 13 CSE341: Programming Languages 14 Spring 2013 CSE341: Programming Languages Spring 2013 Subtyping? Generics? List<Point> inCircle(List<Point> pts, List<Point> inCircle(List<Point> pts, Point center, Point center, double r) { ... } double r) { ... Would like to use inCircle by passing a List<ColorPoint> · We could change the method to be and getting back a List<ColorPoint> <T> List<T> inCircle(List<T> pts, Point center, double r) { ... } Java rightly disallows this: While inCircle would "do nothing wrong" its type does not prevent: - Now the type system allows passing in a List<Point> to - Returning a list that has a non-color-point in it get a List<Point> returned or a List<ColorPoint> to - Modifying pts by adding non-color-points to it get a List<ColorPoint> returned But cannot implement inCircle properly: method body should have no knowledge of type T Spring 2013 CSE341: Programming Languages 15 Spring 2013 CSE341: Programming Languages 16 Bounds Real Java What we want: • The actual Java syntax: <T extends Pt> List<T> inCircle(List<T> pts, <T> List<T> inCircle(List<T> pts, Pt center, Point center, double r) { double r) where T <: Point List<T> result = new ArrayList<T>(); { ... } for(T pt : pts) if(pt.distance(center) < r)</pre> result.add(pt); Caller uses it generically, but must instantiate **T** with some return result; subtype of Point (including Point) } Callee can assume T <: Point so it can do its job Callee must return a List<T> so output will contain only Note: For backward-compatibility and implementation reasons, • elements from pts in Java there is actually always a way to use casts to get around the static checking with generics 😕 With or without bounded polymorphism Spring 2013 CSE341: Programming Languages 17 Spring 2013 CSE341: Programming Languages 18