Deconfined Intersection Types in Java

joint work with Paola Giannini and Betti Venneri

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  - exactly one abstract method (implemented by λ-expressions)
  - any number of default methods (with λ-expressions as receivers)

Our proposal: intersections as first-class types

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- We exploit the polytype nature of λ-expressions

Game example

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interface Flyable { void fly(); }

interface Swimmable { void swim(); }
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```
public class NaviatorDrone implements Flyable, Swimmable {
 public void fly() { ... }
 public void swim() { ... };
}

public  class Pelican implements Flyable, Swimmable {
 public void fly() { ... }
 public void swim() { ... };
}
```

Game example

```
public class Game {
 public static void goAcrossRavine(XXX player,boolean unWatObj){
   System.out.println("Reached the ravine");
   if (unWatObj) {
     player.fly();
     player.swim();
     System.out.println("Picked Object");
     player.swim();
     player.fly();
   } else
   player.fly();
   System.out.println("Crossed the ravine");
 }
 // Other methods of the game using the capabilities of players
 }
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For XXX we need a player implementing `Flyable` and `Swimmable`, which is allowed in our extension

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NO, we can declare `player` of type `X` with

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<X extends Flyable&Swimmable>
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but we cannot declare

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Flyable&Swimmable player = new Pelican();
```

we can only write

```
X player = (X) new Pelican();
```

this introduces a type cast and exposes the type of a local variable!

Discount example

```
interface Discount { double discount(int price); }
interface DelPrice {
 default double delPrice(int price) {
  return (price>30)? 0: 5;
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in our extension

```
public static double
  finalPrice(Discount & DelPrice funPrice, int price){
 return funPrice.discount(price)+funPrice.delPrice(price);
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```

instead in Java (using **var**)

```
public static double finalPrice(int price) {
 var funPrice=(Discount & DelPrice)(x->x-((x>100)? x*0.01: 0));
  return funPrice.discount(price)+funPrice.delPrice(price);
}
```

`funPrice` is fixed and type casted!

Translation aerial view

Source calculus: Java with deconfined intersection types

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Target calculus: standard Java

Translation aerial view

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Target calculus: standard Java

Source calculus versus Target calculus

Translation aerial view

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Target calculus: standard Java

Source calculus versus Target calculus

- same sets of terms

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Target calculus: standard Java

Source calculus versus Target calculus

- same sets of terms
- different types in declarations

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Compilation strategy

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- replace intersections with their most relevant components

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- same sets of terms
- different types in declarations

Compilation strategy

- replace intersections with their most relevant components
- recover the lost type information inserting downcasts (essential to preserve the target types of λ-expressions)

Three mappings

Erasure of types: from intersection types to nominal types

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the erasure maps functional intersections into functional interfaces (essential to preserve target types of λ-expressions)

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$$\left(\left[\frac{\mathcal{D} \;::\; \Gamma \vdash \mathsf{t} : \tau \quad \mathtt{mtype}(\mathsf{m}; \tau) = \overrightarrow{\sigma} \to \sigma \quad \overline{\mathcal{D}} \;::\; \Gamma \vdash^{*} \overline{\mathsf{t}} : \overline{\sigma}}{\Gamma \vdash \mathsf{t}.\mathsf{m}(\overrightarrow{\mathsf{t}}) : \sigma}\,[\text{S-INVK}]\right]\right) =$$

$$(\sigma)\,((\![\mathcal{D}]\!).\mathsf{m}(\overrightarrow{(\![\mathcal{D}]\!)}))$$

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Constructors:

$$[\![\mathsf{C}(\overrightarrow{\sigma}\,\overrightarrow{\mathsf{g}}, \overrightarrow{\tau}\,\overrightarrow{\mathsf{f}})\{\mathsf{super}(\overrightarrow{\mathsf{g}}); \mathsf{this}.\overline{\mathsf{f}} = \overline{\mathsf{f}};\}]\!] = \mathsf{C}(\overrightarrow{|\sigma|}\,\overrightarrow{\mathsf{g}}, \overrightarrow{|\tau|}\,\overrightarrow{\mathsf{f}})\{\mathsf{super}(\overrightarrow{\mathsf{g}}); \mathsf{this}.\overline{\mathsf{f}} = \overline{\mathsf{f}};\}$$

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Methods: $[\![\tau \mathsf{m}(\overrightarrow{\tau}\,\overrightarrow{\mathsf{x}})\{\mathsf{return}\ \ \mathsf{t};\}]\!]^{\mathsf{T}} = |\tau|\mathsf{m}(\overrightarrow{|\tau|}\,\overrightarrow{\mathsf{x}})\{\mathsf{return}\ \ ([\![\mathcal{D}]\!]);\}$
where $\mathcal{D}\ ::\ \mathsf{x} : \overrightarrow{\tau}, \mathsf{this} : \mathsf{T} \vdash^{*} \mathsf{t} : \tau$

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Classes: $[\![\text{class C extends D implements } \overrightarrow{\text{I}}\ \{\overline{\tau}\ \overline{\text{f}};\ \text{K}^S\ \overline{\text{M}^S}\}]\!] =$
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Interfaces: $[\![\text{interface I extends } \overrightarrow{\text{I}} \ \{\overline{\text{H}^S}; \overline{\text{M}^S}\}]\!] =$
$\text{interface I extends } \overrightarrow{\text{I}} \ \{\overline{[\![\text{H}^S]\!]}; \overline{[\![\text{M}^S]\!]^{\text{I}}}\}$

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- ignores casts on terms different from λ-expressions
- uses casts on λ-expressions as target types

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Semantic preservation

$$t_1 \longrightarrow_S t_2 \longrightarrow_S \ldots t_i \longrightarrow_S \ldots$$

implies

$$([\![t_1]\!]) \longrightarrow_T^* t_2' \longrightarrow_T^* \ldots t_i' \longrightarrow_T^* \ldots$$

where $([\![t_i]\!]) \approx t_i'$, $i > 1$

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We gave a compilation of typed programs in *Java with deconfined intersection types* into *Java* typed programs preserving typing and semantics

Future work

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- and compile this notion of traits into Java

Happy Birthday Maurizio