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Concrete syntax

{record {x 1}}

Abstract syntax

(record x=(num 1))

Record defn-type

(record (cons (fld 'x (num 1)) empty))



$\emptyset \vdash \{\text{record } \{x\ 1\}\} : \{\text{Record } \{x \text{ Pos}\}\}$

Record x:Pos

(t/record (cons (field-type 'x (t/pos)) empty))

$\emptyset \vdash \{\text{record } \{x\ 1\} \{y\ 2\}\} : \{\text{Record } \{x \text{ Pos}\} \{y \text{ Pos}\}\}$
or $\{\text{Record } \{x\ y \text{ Pos}\}\}$

syntactic sugar

(t/record (list (field-type 'x (t/pos)) (field-type 'y (t/pos))))

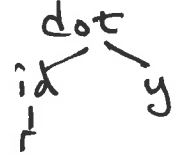
$\emptyset \vdash \{\text{record}\} : \{\text{Record}\}$

(t/record empty)

{dot r y}

(dot (id r) y)

(dot (id 'r) 'y)



$r : (\text{record } y : \text{Pos}) \vdash (\text{dot } (\text{id } r) y) : \text{Pos}$

$r : (\text{record } x : \text{Pos}, y : \text{Pos}) \vdash (\text{dot } (\text{id } r) y) : \text{Pos}$

$\emptyset \vdash \underbrace{(\text{lam } r \text{ (Record } x:\text{Pos)} \text{ (dot (id } r) x))}_{e\text{Get}x} : (\text{Record } x:\text{Pos}) \rightarrow \text{Pos}$

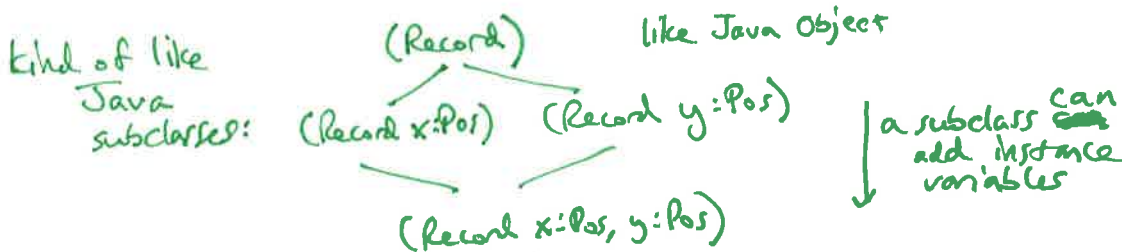
$\emptyset \vdash (\text{app } e\text{Get}x \text{ (record } x=(\text{num } 1), y=(\text{num } 2))) : \text{Pos}$

$\emptyset \vdash e\text{Get}x : (\text{Record } x:\text{Pos}) \rightarrow \text{Pos}$ $\emptyset \vdash \text{(record } x=(\text{num } 1), y=(\text{num } 2)) : (\text{Record } x:\text{Pos})$
type-app

$\emptyset \vdash \text{(record } x=(\text{num } 1), y=(\text{num } 2)) : (\text{Record } x:\text{Pos}, y:\text{Pos})$ $(\text{Record } x:\text{Pos}, y:\text{Pos}) <: (\text{Record } x:\text{Pos})$
type-sub

"width subtyping"

$(\text{Record } x:\text{Pos}, y:\text{Pos}) <: (\text{Record } x:\text{Pos})$
 $(\text{Record } x:\text{Pos}, y:\text{Pos}) <: (\text{Record } y:\text{Pos})$



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$$\emptyset \vdash \underbrace{(\text{lam } r \text{ (Record } y:\text{Rat)} \text{ (dot (id } r) \text{ } y))}_{\text{eGety}} : (\text{Record } y:\text{Rat}) \rightarrow \text{Rat}$$

$$\emptyset \vdash (\text{app eGety (record } y=(\text{num } 2))) : \text{Rat}$$

$$\frac{\emptyset \vdash \text{eGety} : (\text{Record } y:\text{Rat}) \rightarrow \text{Rat} \quad \emptyset \vdash (\text{record } y=(\text{num } 2)) : (\text{Record } y:\text{Rat})}{\emptyset \vdash (\text{app eGety (record } y=(\text{num } 2))) : \text{Rat}}$$

Type-app

$$q : (\text{Record } y:\text{Pos}) \vdash (\text{app eGety (id } q)) :$$

$$\emptyset \vdash (\text{record } y=(\text{num } 2)) : (\text{Record } y:\text{Pos})$$

$$\frac{\text{Pos} <: \text{Rat}}{(\text{Record } y:\text{Pos}) <: (\text{Record } y:\text{Rat})}$$

"depth subtyping"

$$(\text{ite } \overset{(\text{id 'b})}{\text{true}} \text{ (record } x=1, y=2) \text{ (record } y=1, z=1))) : (\text{Record } y:\text{Pos})$$

(Record)

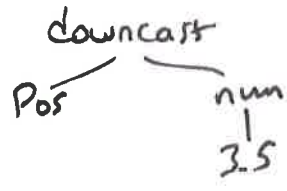
④

'downcast'

{downcast Pos 3.5}

(downcast Pos (num 3.5))

(downcast (t/pos)
(num 3.5))



$$\frac{\Gamma \vdash e : B}{\Gamma \vdash (\text{downcast } A \ e) : A} \text{Type-downcast}$$

$$\frac{e \Downarrow v \quad \emptyset \vdash v : A}{(\text{downcast } A \ e) \Downarrow v}$$

(downcast Pos ^(num) 3)) \Downarrow (num 3)

(downcast Pos (num -3)) $\not\Downarrow$ error

$$\frac{eIdx : Pos}{(idx \ eStr \ eIdx)}$$

x: Int \vdash
 (ite (< x 0) (str "bad")
 (downcast Pos (idx (str "abc") (id x))))