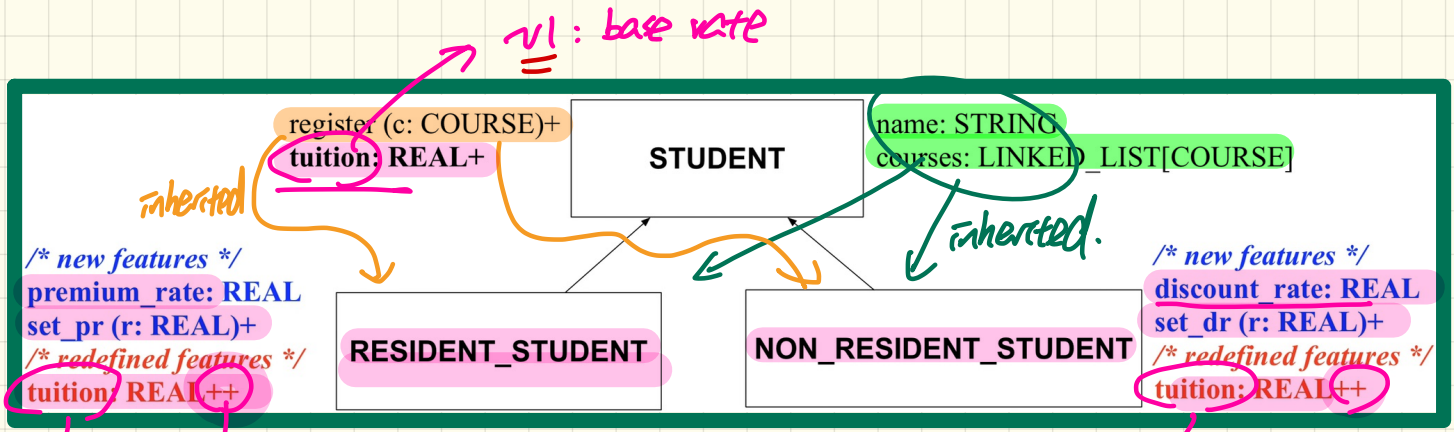
Lecture 7

Part 5

Static vs. Dynamic Types

Revisit: Inheritance for Code Reuse



Static Type vs. Dynamic Type

S. S = new RS(..);
;
S = new NRS(..);

- In Java:

```
Student s = new Student("Alan");
Student rs = new ResidentStudent("Mark");
```

- In Eiffel:

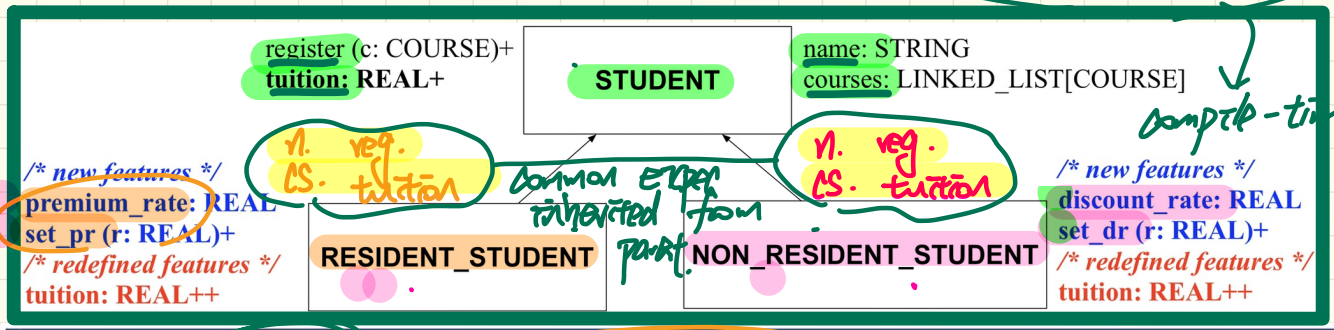
```
local s: STUDENT
      rs: STUDENT
do create {STUDENT} s.make ("Alan")
   create {RESIDENT_STUDENT} rs.make ("Mark")
```

  - In Eiffel, the *dynamic type* can be omitted if it is meant to be the same as the *static type*:

```
local s: STUDENT
do create.s.make ("Alan")
```

create {STUDENT} s.make("Alan")

Student Classes (with Inheritance): Expectations




```
s1, s2, s3: STUDENT ; rs: RESIDENT_STUDENT ; nrs : NON_RESIDENT_STUDENT
create {STUDENT} s1.make ("S1")
create {RESIDENT_STUDENT} s2.make ("S2")
create {NON_RESIDENT_STUDENT} s3.make ("S3")
create {RESIDENT_STUDENT} rs.make ("RS")
create {NON_RESIDENT_STUDENT} nrs.make ("NRS")
```

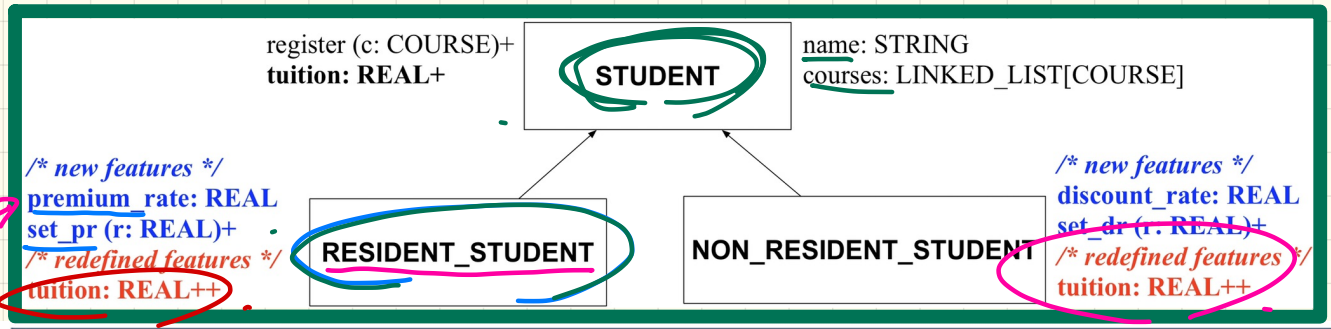
	name	courses	reg	tuition	pr	set_pr	dr	set_dr
s1	✓	✓	✓	✓	✗	✗	✗	✗
s2					✗			
s3								
rs								
nrs								

Lecture 7

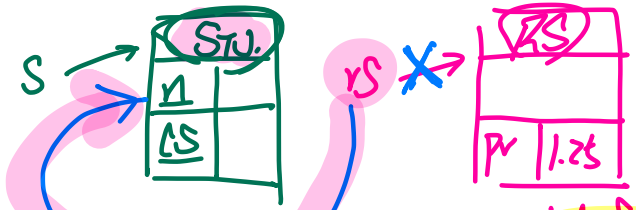
Part 6

Intuition:
Polymorphism vs. Dynamic Binding

Polymorphism: Intuition




```
1  local
2    s: STUDENT
3    rs: RESIDENT_STUDENT
4  do
5    create s.make ("Stella")
6    create rs.make ("Rachael")
7    rs.set_pr (1.25)
8  ✓ s := rs /* Is this valid? */
9  X rs := s /* Is this valid? */
```



not compiled. opposite should be true

Assume: `rs := s` Compiled.

⇒ Runtime: execute the re-assignment

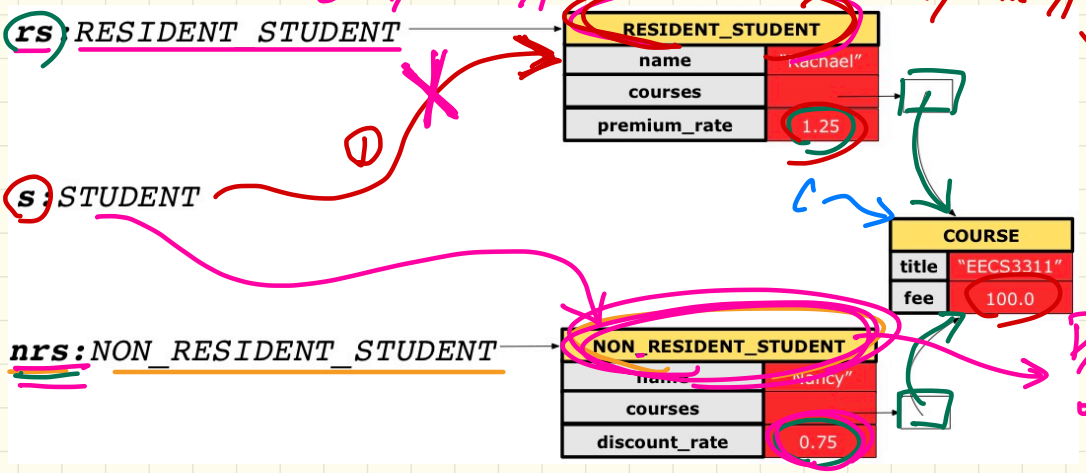
Q. Expectations on rs?

rs' ST: n. LS. reg. tuition

pr set_pr.

Dynamic Binding: Intuition

```
1  local c : COURSE ; s : STUDENT
2        .rs : RESIDENT_STUDENT ; nrs : NON_RESIDENT_STUDENT
3  do create c.make ("EECS3311", 100.0)
4     create {RESIDENT_STUDENT} rs.make("Rachael")
5     create {NON_RESIDENT_STUDENT} nrs.make("Nancy")
6     rs.set_pr(1.25); rs.register(c)
7     nrs.set_dr(0.75); nrs.register(c)
8  ①  s := rs  ; check s.tuition = 125.0 end
9  ②  s := nrs ; check s.tuition = 75.0 end
```

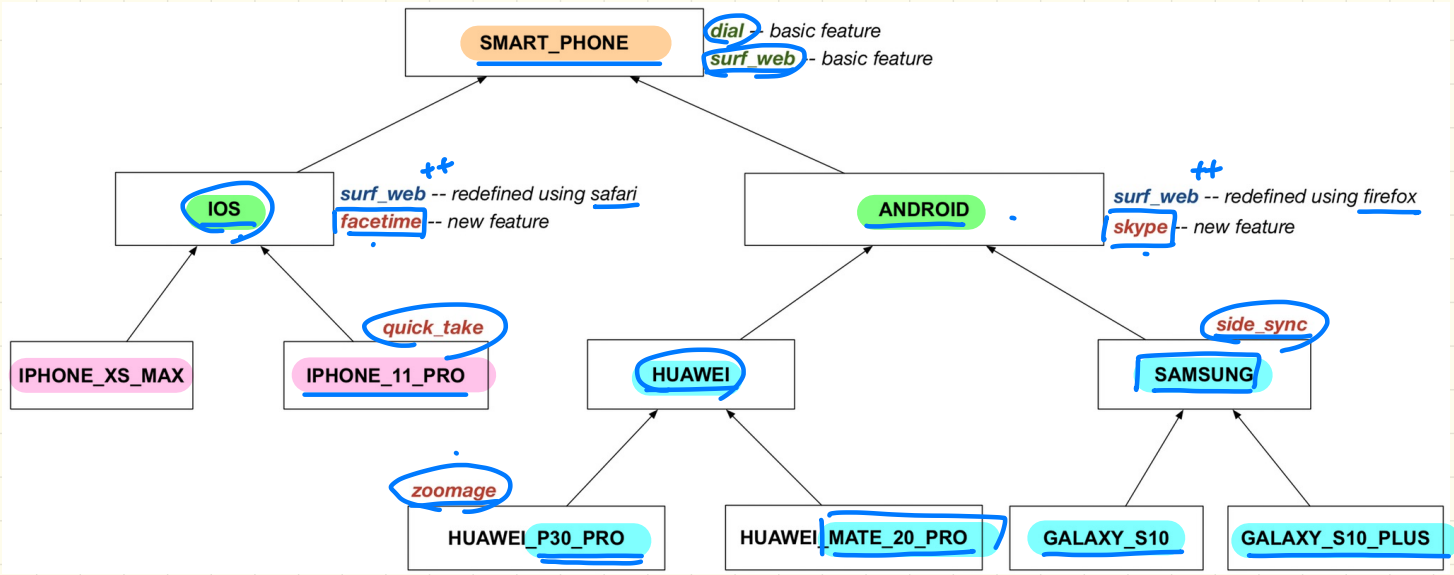


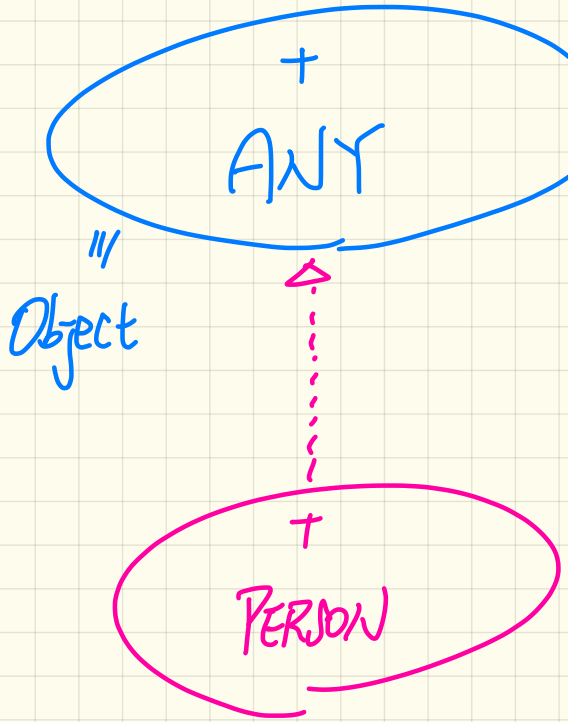
Lecture 7

Part 7

Multi-Level Inheritance Hierarchy

Multi-Level Inheritance Hierarchy of Smartphones





is_equal ← equals()

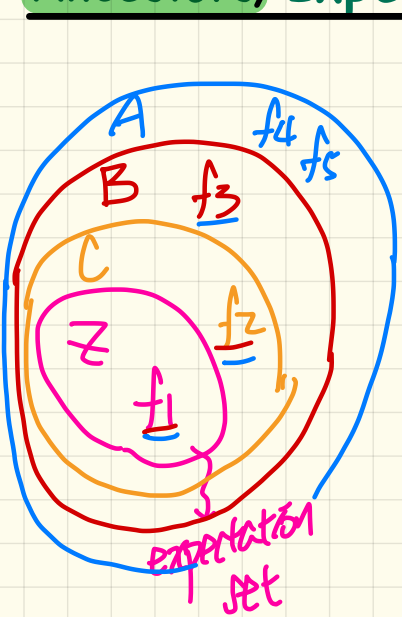
out ← to_string()

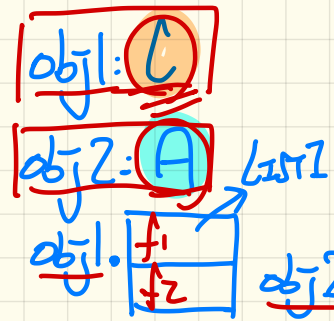
inherit ANY

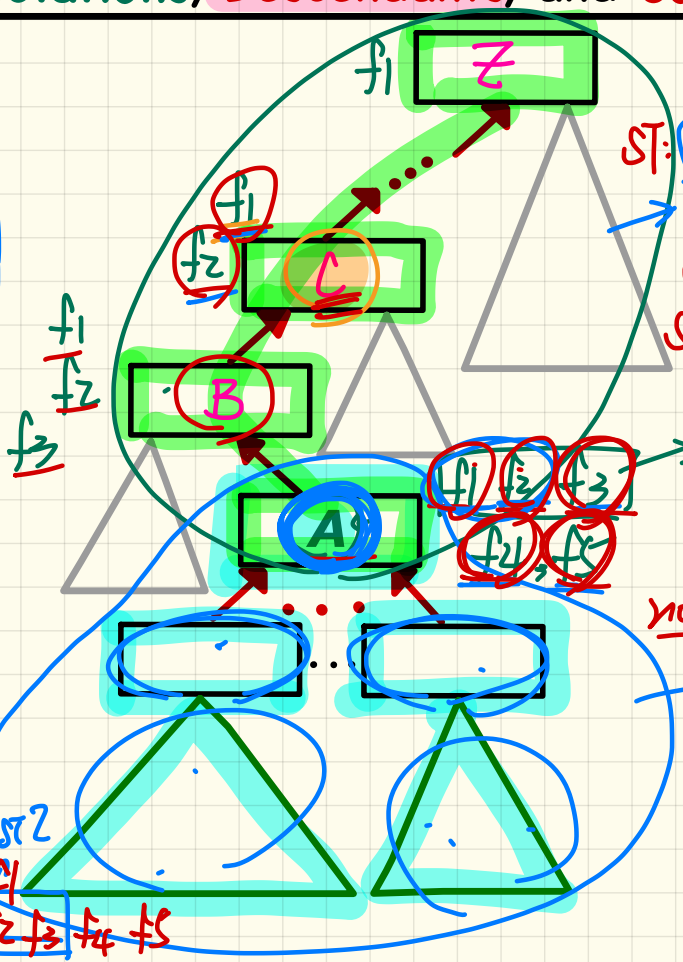
redefine is_equal end

is_equal(...): Bool

Ancestors, Expectations, Descendants, and Code Reuse



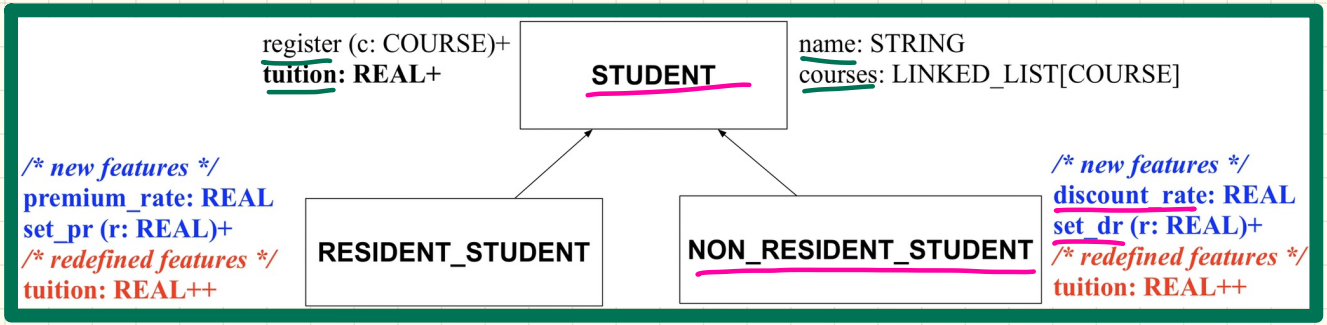


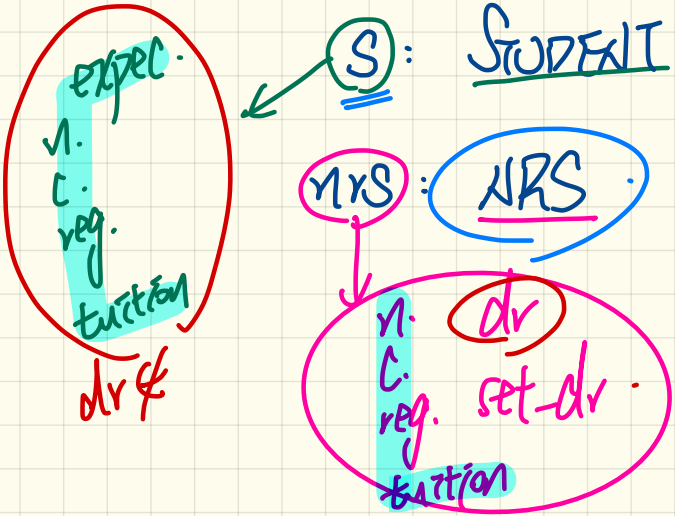


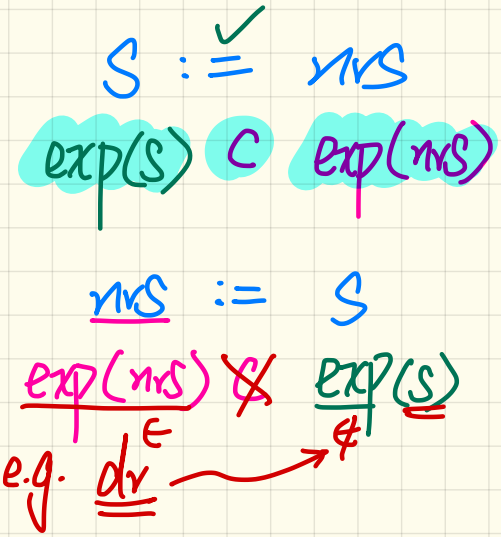
can satisfy?
ancestors.
ST: C
obj1
:=
ST: A
obj2
obj2
:=
obj1
ST: A
ST: C
inherited from ancestors of F1

not valid : A (f3, f4, f5)
descendants of A.
cannot be fulfilled by C.

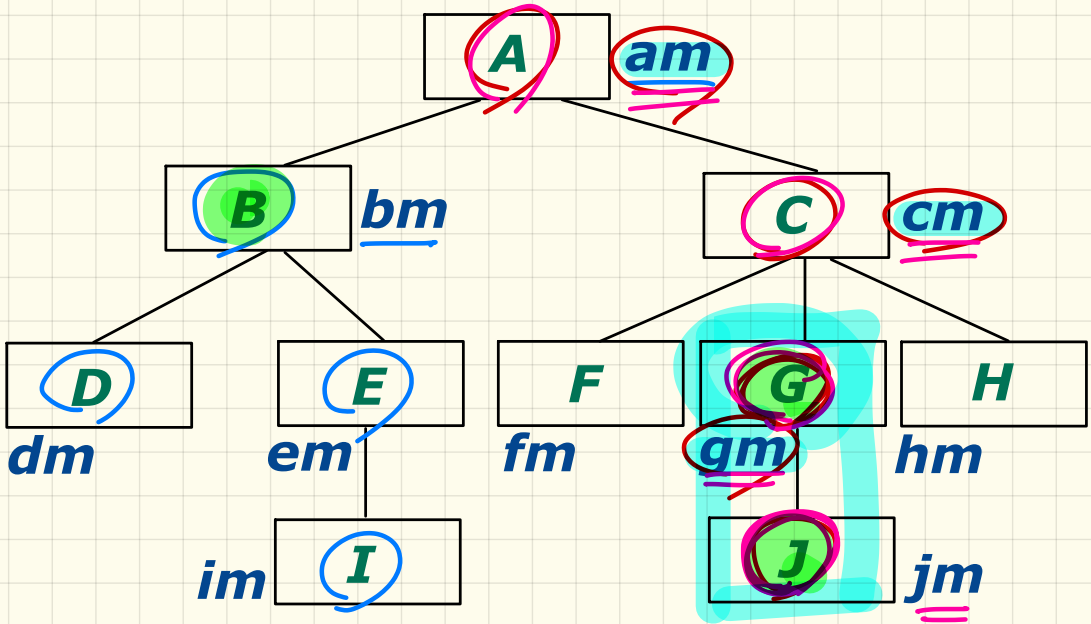
Substitutions by a Descendant Type





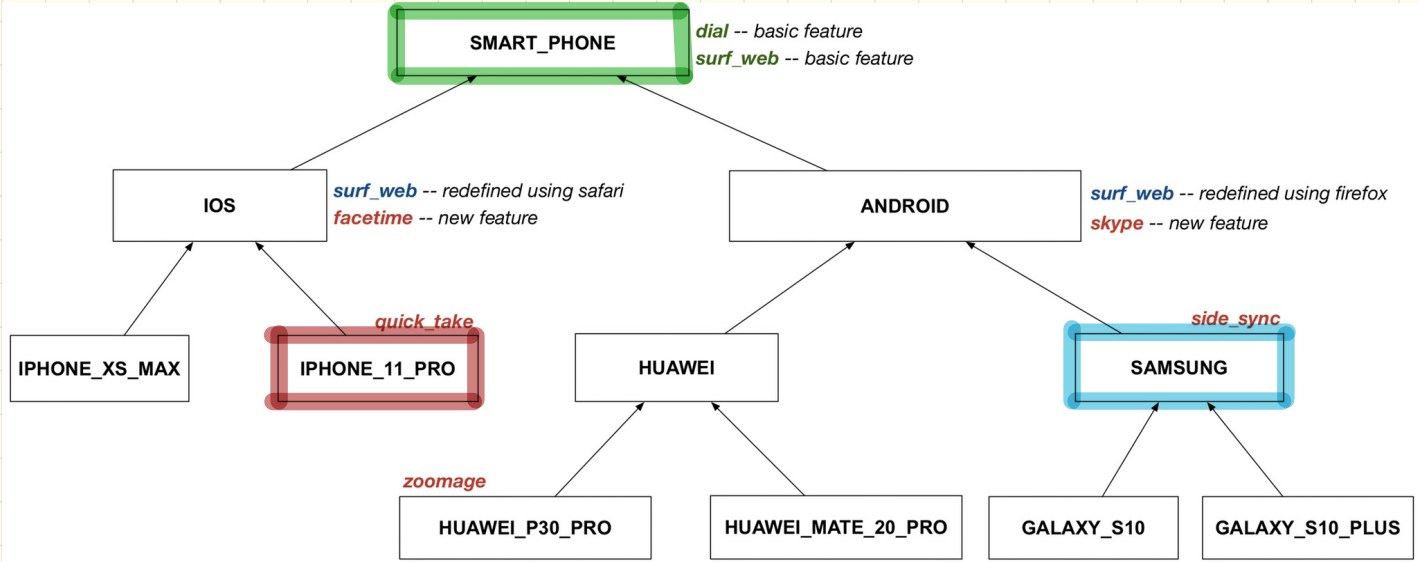


Inheritance Forms a Type Hierarchy (1)



	ancestors	expectations	descendants
B	{B, A}	{bm, am}	{B, D, E, I}
G	{G, C, A}	{am, cm, gm}	{G, J}
J	{J, G, C, A}	{jm, gm, cm, am}	{J}

Inheritance Forms a Type Hierarchy (2)



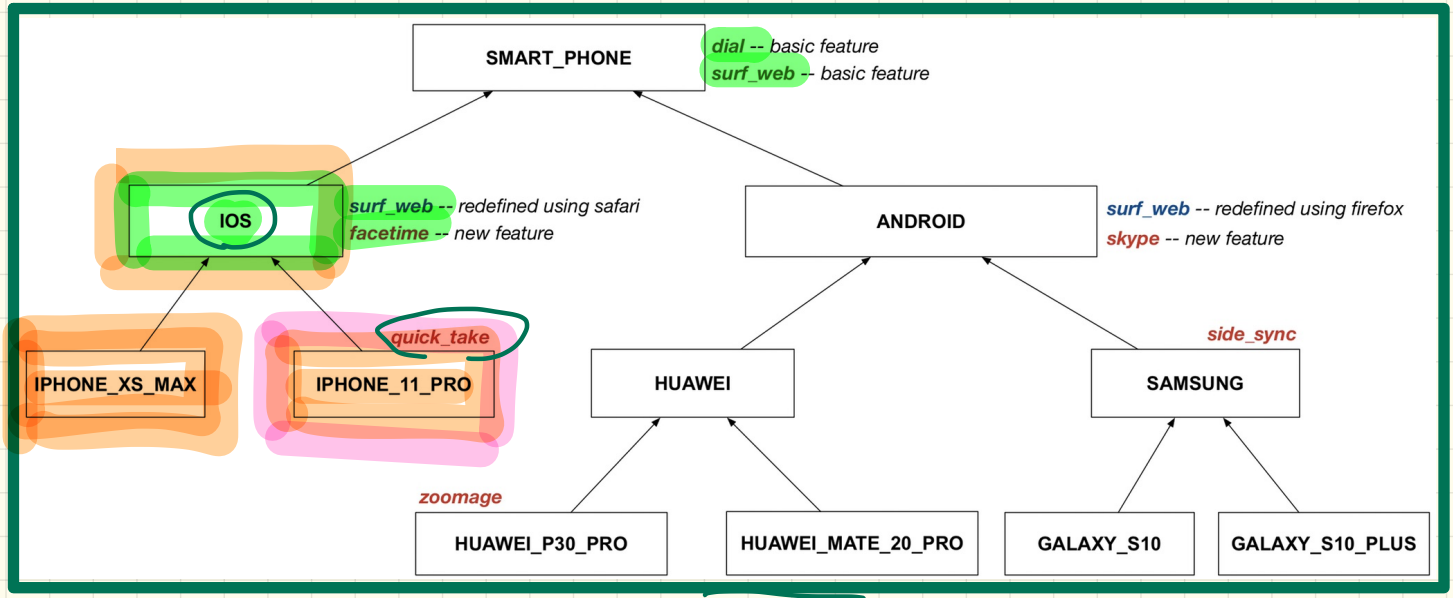
	ancestors	expectations	descendants

Lecture 7

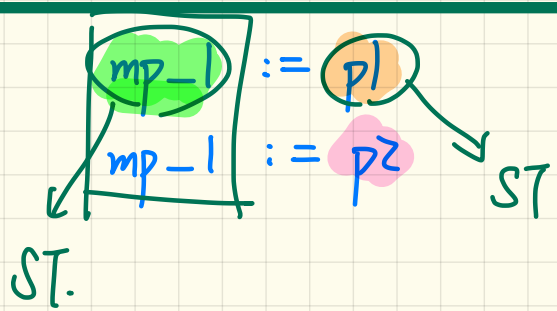
Part 8

Rules of Substitutions via Assignments

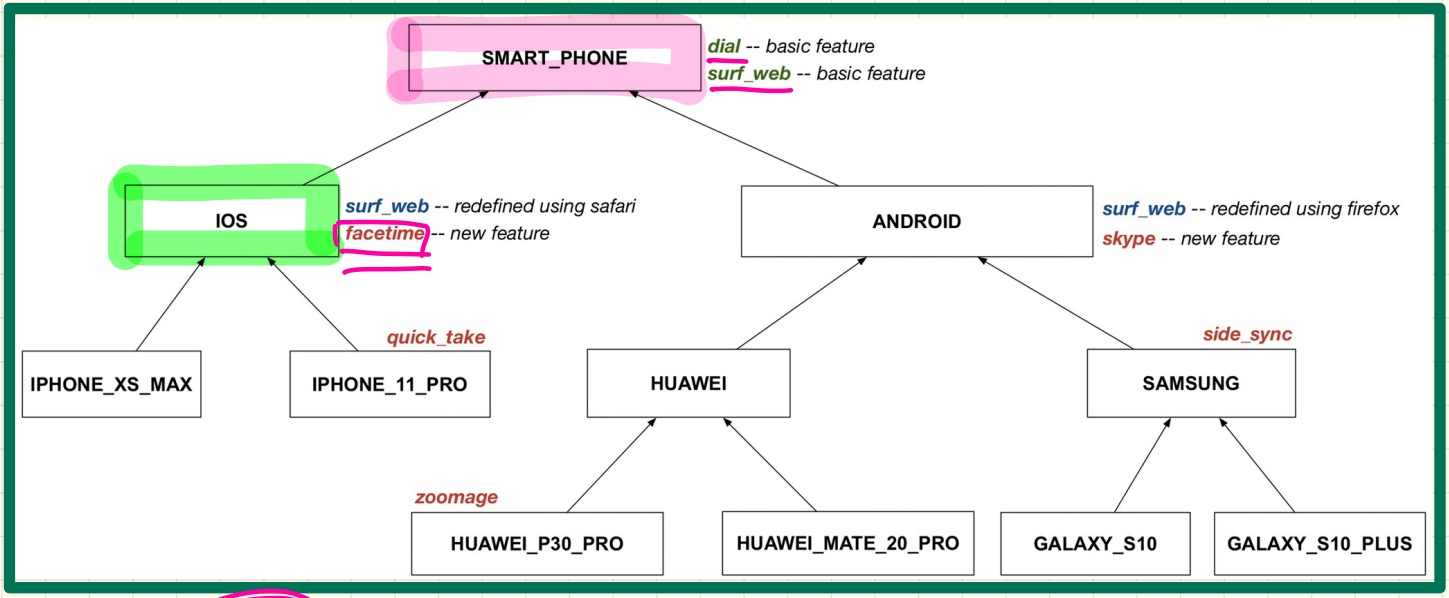
Rules of Substitutions (1)



mp_1: IOS
p1: I_PHONE_XS_MAX
p2: I_PHONE_11_PRO



Rules of Substitutions (2)



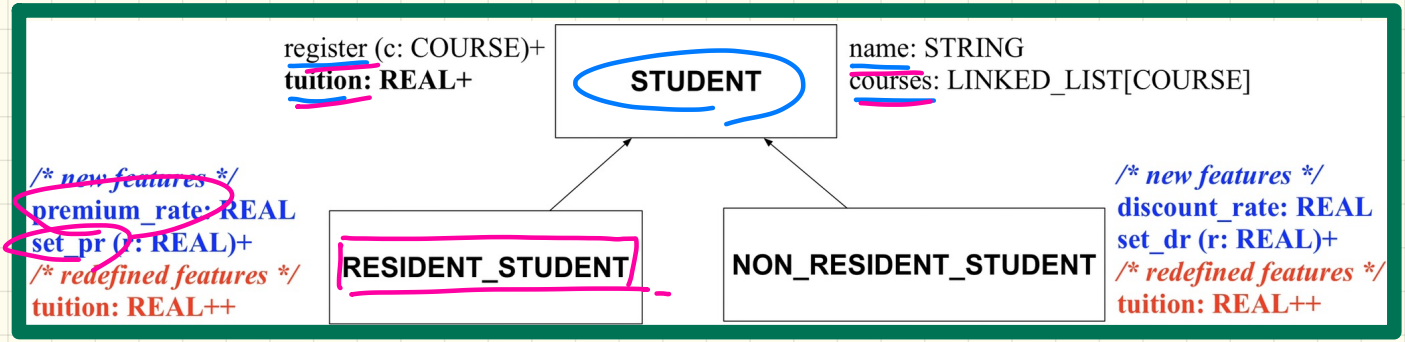
mp_2: IOS
p3: SMART_PHONE

mp_2 := p3

facetime

not safe for substituting mp_2 e.g. facetime

Reference Variables: Static Type



Design 1:

jim: STUDENT

jim.
- n
- cs
- reg
- tuition

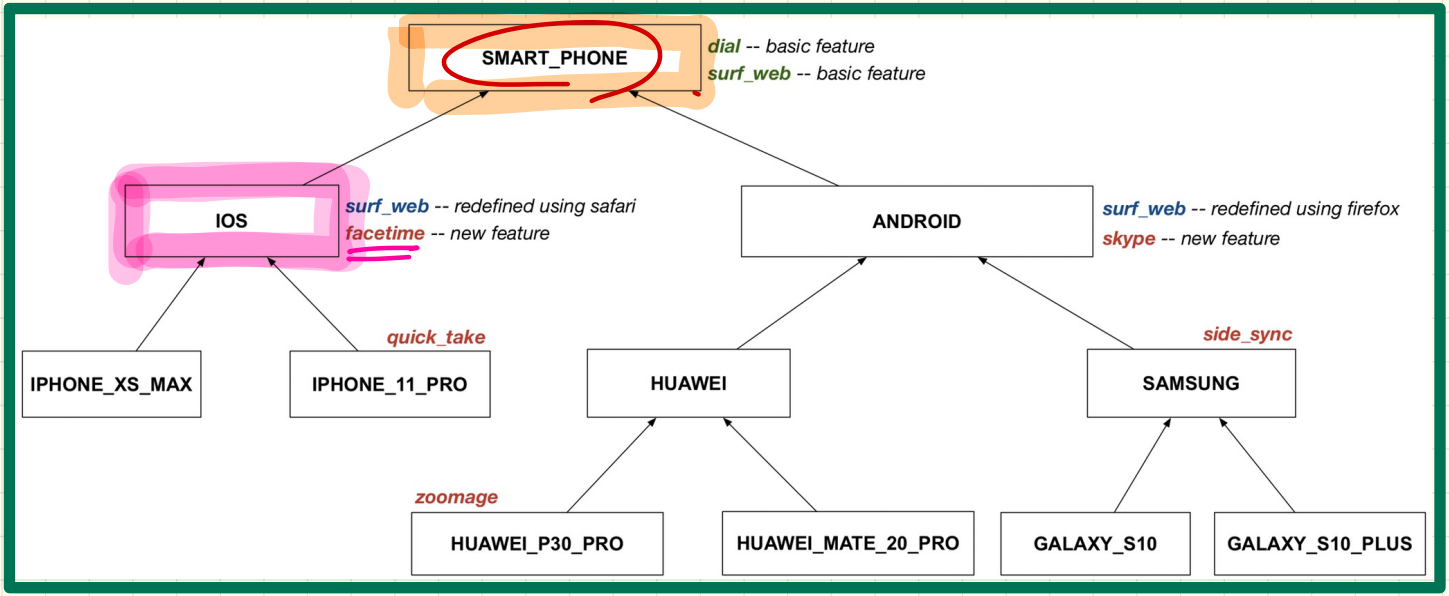
Design 2:

under expectations on jim.

jim: RESIDENT_STUDENT

jim.
- n.
- cs.
- reg.
- tuition
- pr.
- set_pr

Reference Variables: Static Type



Design 1:

mp: **SMART_PHONE**

mp. facetime ✗

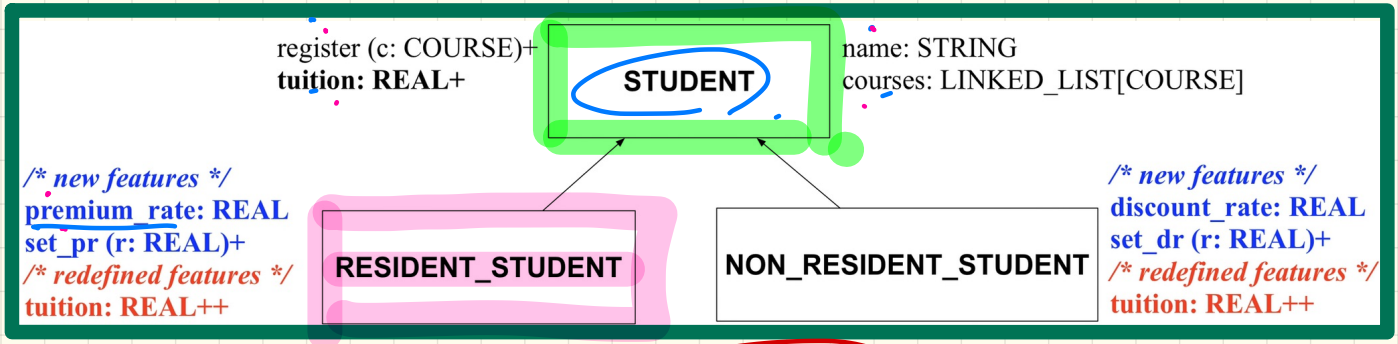
Design 2:

mp: **IOS**

→ wider expectation.

e.g. facetime.

Change of Dynamic Type (1)



Design 1:

exp(STUDENT)

jim: STUDENT

create { ? } jim.make(...)

Jim → ? → STU. RS. NRS.

Design 2:

ST has wider expec, making there fewer choices of classes that can

exp(RS)

jim: RESIDENT_STUDENT

create { } jim.make(...)

RS

fulfill its expectations.

X STUDENT

Change of Dynamic Type (2)

```
1  test_polymorphism_students
2   local
3     jim: STUDENT
4     rs: RESIDENT_STUDENT
5     nrs: NON_RESIDENT_STUDENT
6   do
7    create {STUDENT} jim.make ("J. Davis")
8    create {RESIDENT_STUDENT} rs.make ("J. Davis")
9    create {NON_RESIDENT_STUDENT} nrs.make ("J. Davis")
10    jim := rs   ✓
11    rs := jim   ×
12    jim := nrs  ✓
13    nrs := jim  ×
14   end
```

ST: RS

ST: S

changes DT of Jim. from S. to RS.

changes DT of Jim from RS to NRS.

Jim

rs

nrs

STUDENT	
n.	"J. Davis"
cs.	

RESIDENT_S.	
n.	"J. Davis"
cs.	
pr.	

NON_RESI_S.	
n.	"J. Davis"
cs.	
dr.	

Testing of Dynamic Binding

RESIDENT_S.	
n.	
cs.	
pr.	

NON_RESI_S.	
n.	
cs.	
dr.	

STUDENT	
n.	
cs.	

```
class STUDENT
create make
feature -- Attributes
  name: STRING
  courses: LINKED_LIST[COURSE]
feature -- Commands that can be used as constructors.
  make (n: STRING) do name := n ; create courses.make end
feature -- Commands
  register (c: COURSE) do courses.extend (c) end
feature -- Queries
  tuition: REAL
    local base: REAL
    do base := 0.0
       across courses as c loop base := base + c.item.fee end
       Result := base
    end
end
```

```
test_dynamic_binding_students: BOOLEAN
  local
    jim: STUDENT
    rs: RESIDENT_STUDENT
    nrs: NON_RESIDENT_STUDENT
    c: COURSE
  do
    create c.make ("EECS3311", 500.0)
    create {STUDENT} jim.make ("J. Davis")
    create {RESIDENT_STUDENT} rs.make ("J. Davis")
    rs.register (c)
    rs.set_pr (1.5)
    jim := rs
    Result := jim.tuition = 750.0
    check Result end
    create {NON_RESIDENT_STUDENT} nrs.make ("J. Davis")
    nrs.register (c)
    nrs.set_dr (0.5)
    jim := nrs
    Result := jim.tuition = 250.0
end
```

COURSE	
t.	
fee	

```
class
  RESIDENT_STUDENT
inherit
  STUDENT
    redefine tuition end
create make
feature -- Attributes
  premium_rate: REAL
feature -- Commands
  set_pr (r: REAL) do premium_rate := r end
feature -- Queries
  tuition: REAL
    local base: REAL
    do base := Precursor ; Result := base * premium_rate end
end
```

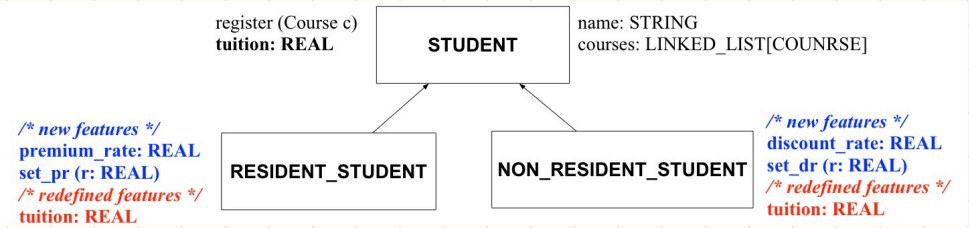
```
class
  NON_RESIDENT_STUDENT
inherit
  STUDENT
    redefine tuition end
create make
feature -- Attributes
  discount_rate: REAL
feature -- Commands
  set_dr (r: REAL) do discount_rate := r end
feature -- Queries
  tuition: REAL
    local base: REAL
    do base := Precursor ; Result := base * discount_rate end
end
```

Lecture 7

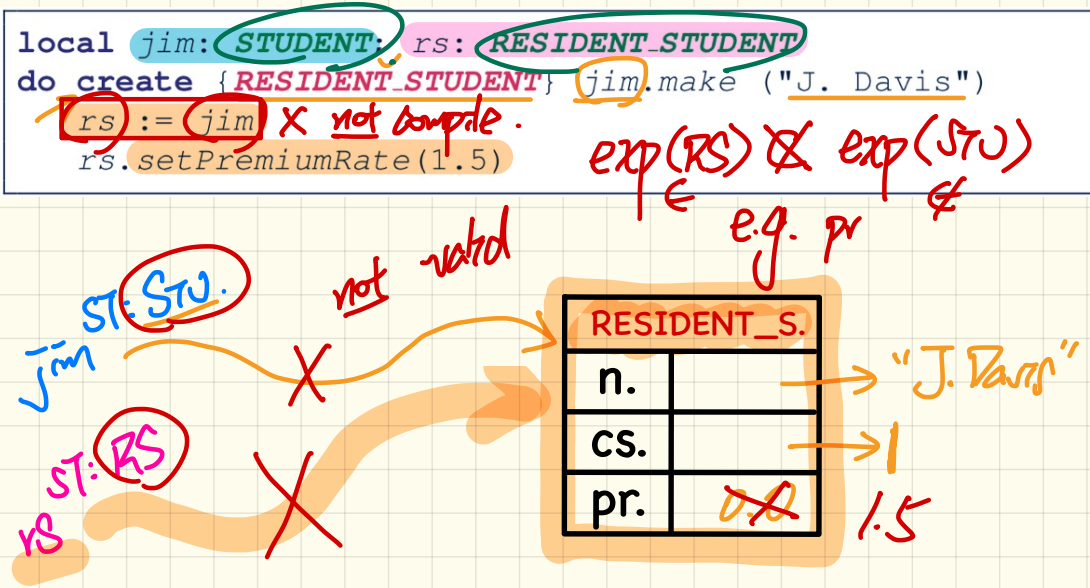
Part 9

Type Casting

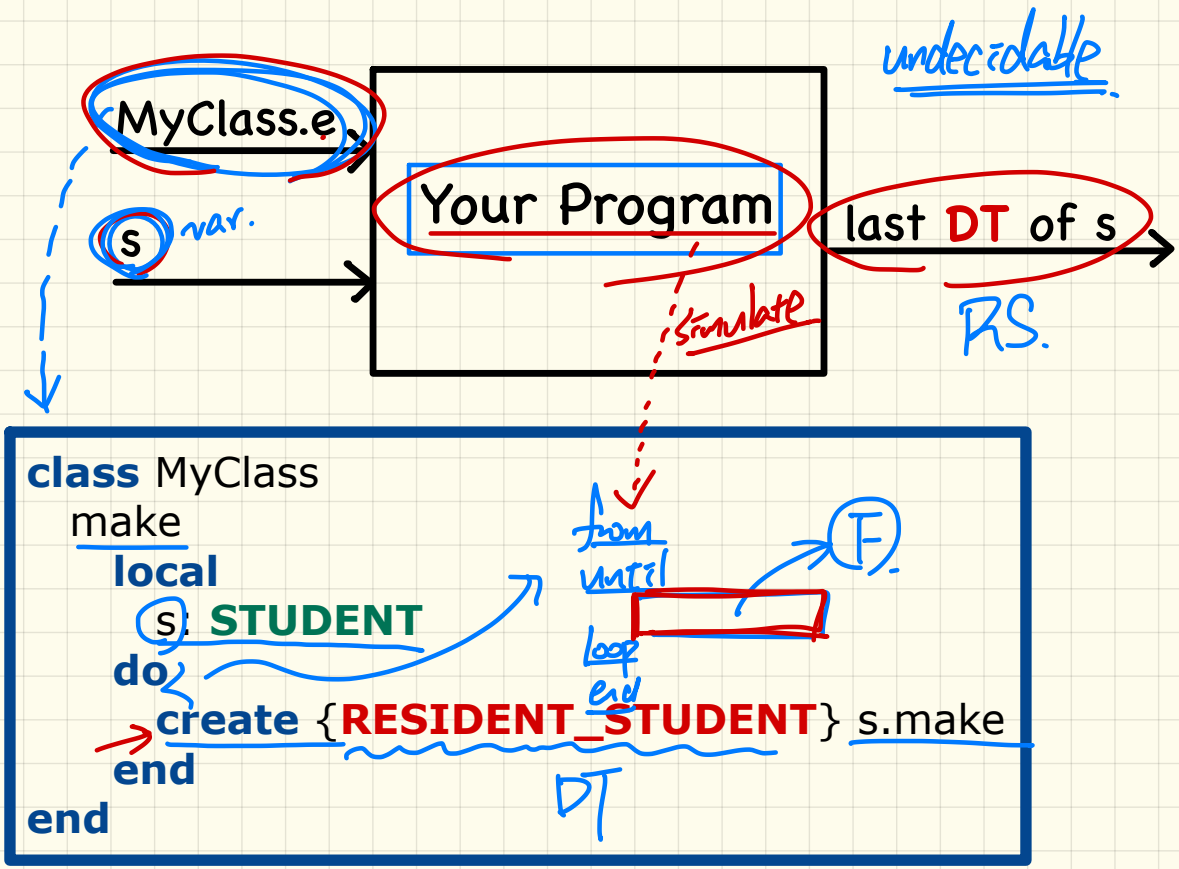
Type Cast: Motivation




```
1  local jim: STUDENT; rs: RESIDENT_STUDENT
2  do create {RESIDENT_STUDENT} jim.make ("J. Davis")
3    rs := jim
4    rs.setPremiumRate(1.5)
```



Inferring the DT of a Variable is Undecidable



Type Cast: Syntax

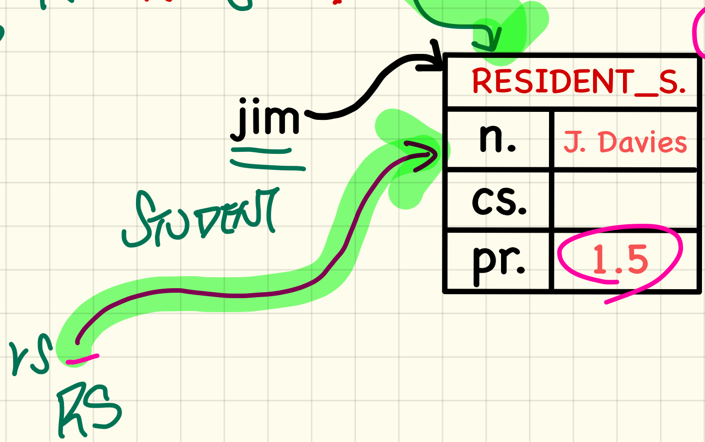
```
check attached {RESIDENT_STUDENT} jim as rs_jim then
  rs := rs_jim
  rs.set_pr (1.5)
end
```

① if F ⇒ assertion violation

can the DT of jim fulfill the exp of RS

① eval to true
② alias to what jim is pointing to with ST RS.

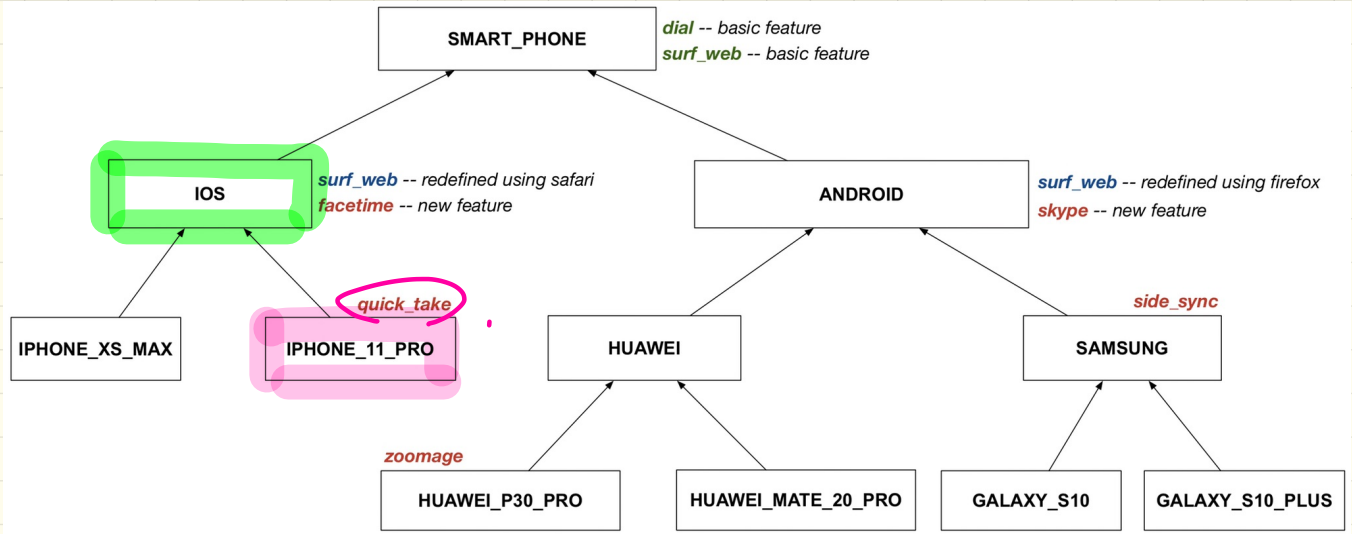
ST: RS. rs_jim



②. if attached {RS} jim as r then
  rs := r
  rs.set_pr(1.5)
else

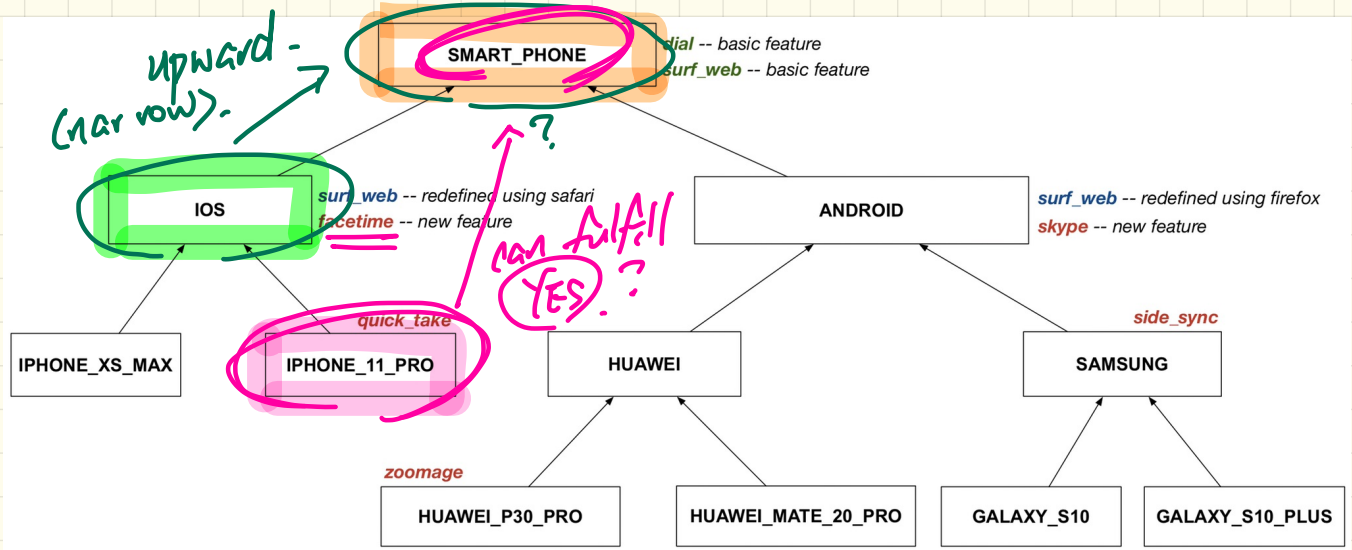
end

Violation-Free Cast: Upwards or Downwards (1)



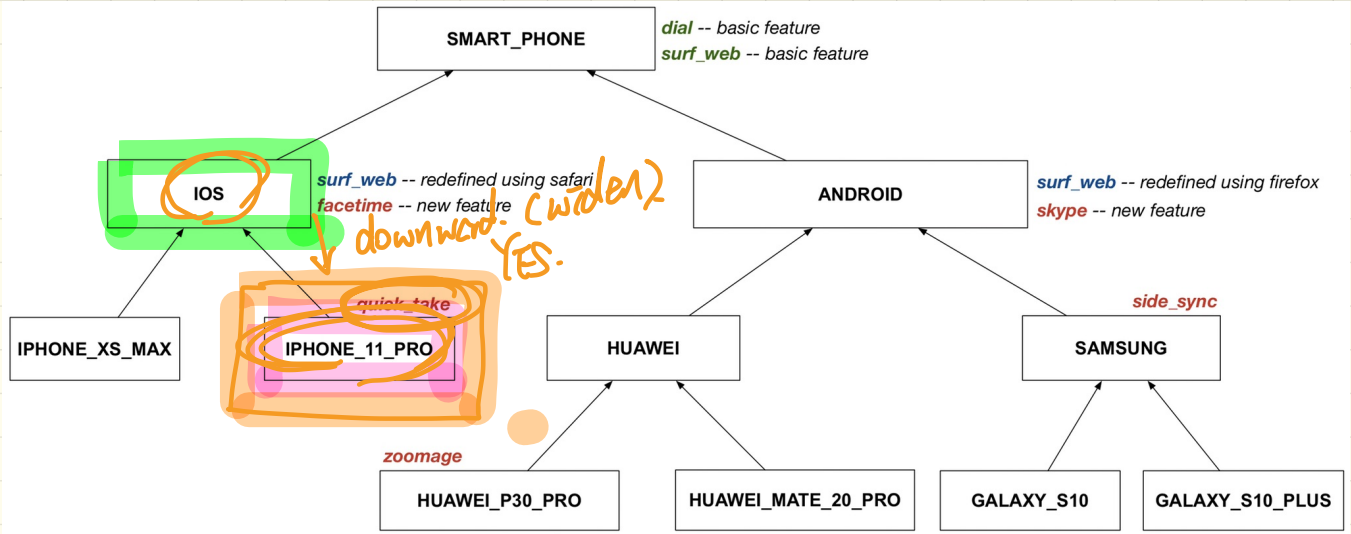

```
my_phone: IOS
create {IPHONE_11_PRO} my_phone.make
  -- can only call features defined in IOS on myPhone
  -- dial, surf_web, facetime ✓  quick_take, skype, side_sync, zoomage ×
check attached {SMART_PHONE} my_phone as sp then
  -- can now call features defined in SMART_PHONE on sp
  -- dial, surf_web ●  facetime, quick_take, skype, side_sync, zoomage ●
end
check attached {IPHONE_11_PRO} my_phone as ip11_pro then
  -- can now call features defined in IPHONE_11_PRO on ip11_pro
  -- dial, surf_web, facetime, quick_take ●  skype, side_sync, zoomage ●
end
```

Violation-Free Cast: Upwards or Downwards (2)



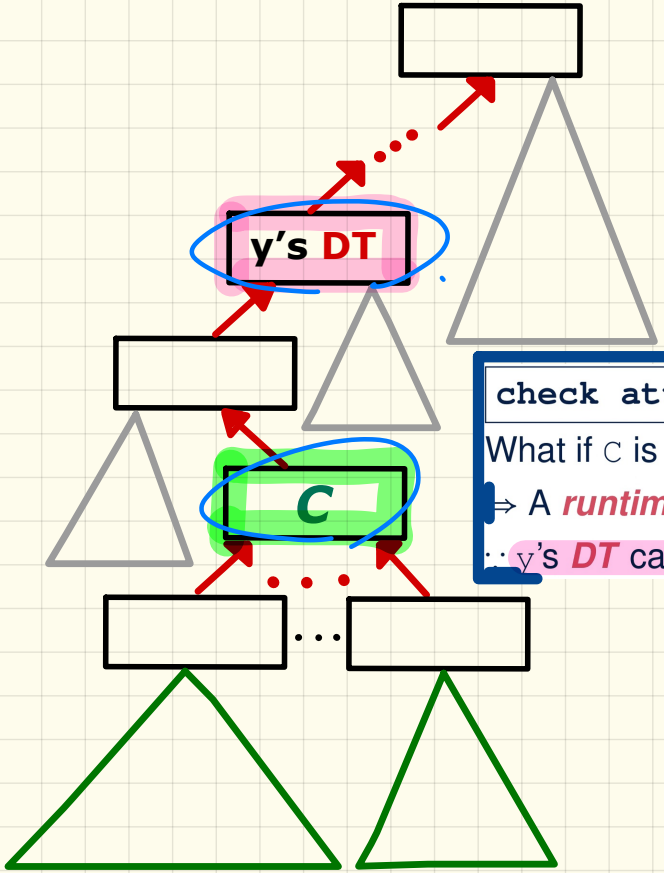

```
my_phone: IOS
create {IPHONE_11_PRO} my_phone.make
  -- can only call features defined in IOS on myPhone
  -- dial, surf_web, facetime, quick_take, skype, side_sync, zoomage
check attached {SMART_PHONE} my_phone as sp then
  -- can now call features defined in SMART_PHONE on sp
  -- dial, surf_web ✓  facetime, quick_take, skype, side_sync, zoomage ×
end
check attached {IPHONE_11_PRO} my_phone as ip11_pro then
  -- can now call features defined in IPHONE_11_PRO on ip11_pro
  -- dial, surf_web, facetime, quick_take, skype, side_sync, zoomage
end
```

Violation-Free Cast: Upwards or Downwards (3)




```
my_phone: IOS
create {IPHONE_11_PRO} my_phone.make
  -- can only call features defined in IOS on myPhone
  -- dial, surf_web, facetime, quick_take, skype, side_sync, zoomage
check attached {SMART_PHONE} my_phone as sp then
  -- can now call features defined in SMART_PHONE on sp
  -- dial, surf_web, facetime, quick_take, skype, side_sync, zoomage
end
check attached {IPHONE_11_PRO} my_phone as ip11_pro then
  -- can now call features defined in IPHONE_11_PRO on ip11_pro
  -- dial, surf_web, facetime, quick_take ✓  skype, side_sync, zoomage ×
end
```

Ancestors, Expectations, Descendants, and Code Reuse



can the DT of y fulfill the exper. on C?

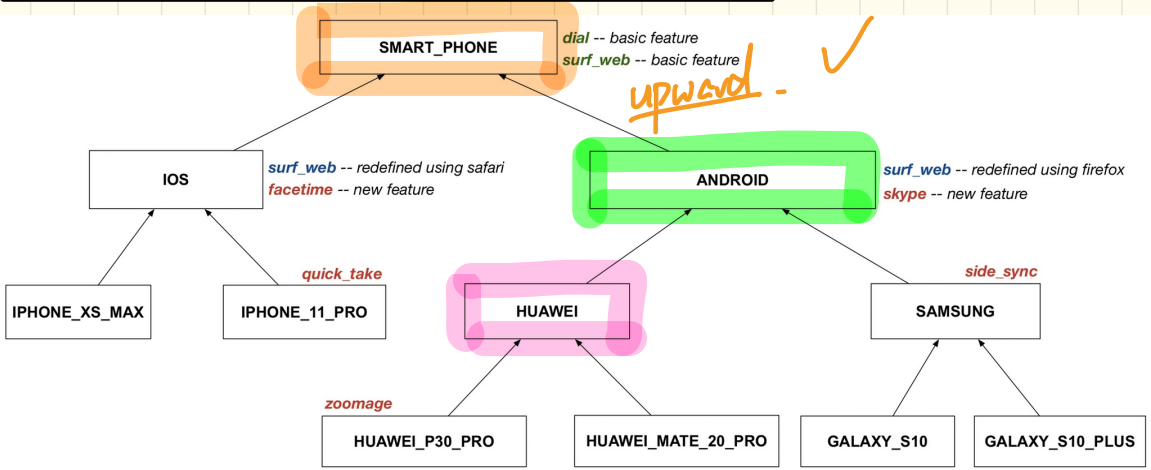
`check attached {C} (y) then ... end` *always compiles*

What if C is not an **ancestor** of y's ***DT***?

⇒ A ***runtime*** assertion violation occurs!

∴ y's ***DT*** cannot fulfill the expectation of C.

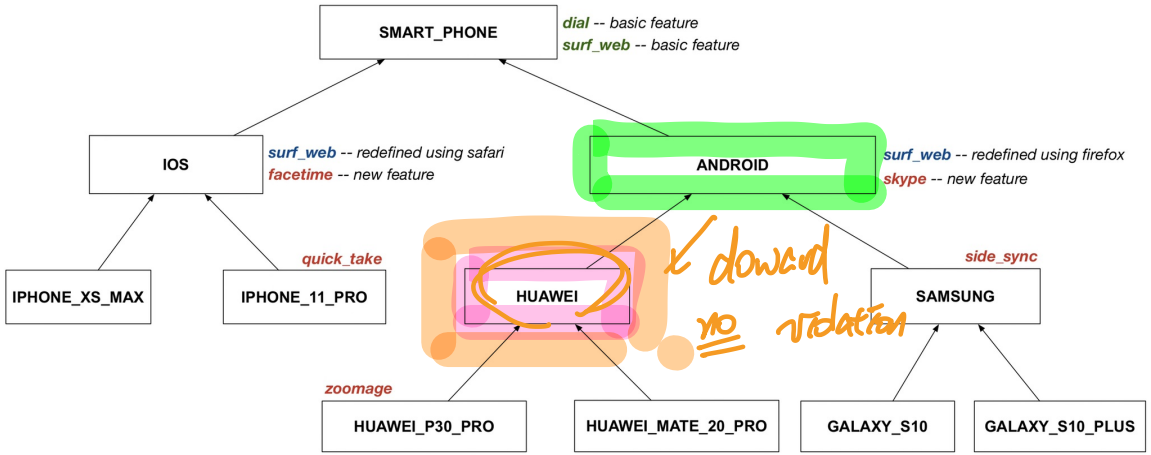
Cast Violation at Runtime (1)




```
test_smart_phone_type_cast_violation
  local mine: ANDROID
  do create {HUAWEI} mine.make
    -- ST of mine is ANDROID; DT of mine is HUAWEI
    check attached {SMART_PHONE} mine as sp then ... end
    -- ST of sp is SMART_PHONE; DT of sp is HUAWEI
    check attached {HUAWEI} mine as huawei then ... end
    -- ST of huawei is HUAWEI; DT of huawei is HUAWEI
    check attached {SAMSUNG} mine as samsung then ... end
    -- Assertion violation
    -- ∵ SAMSUNG is not ancestor of mine's DT (HUAWEI)
    check attached {HUAWEI_P30_PRO} mine as p30_pro then ... end
    -- Assertion violation
    -- ∵ HUAWEI_P30_PRO is not ancestor of mine's DT (HUAWEI)
end
```

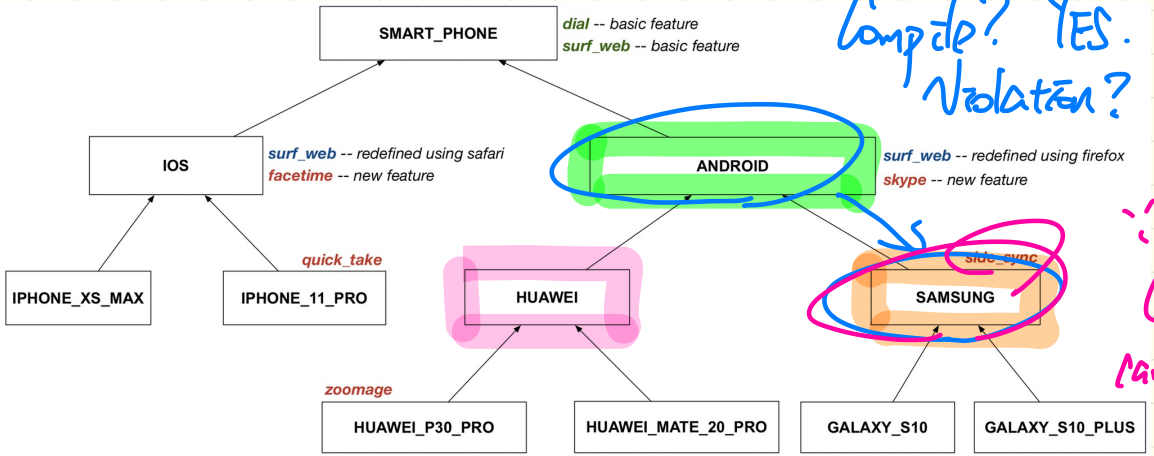
No. violation

Cast Violation at Runtime (2)




```
test_smart_phone_type_cast_violation
  local mine: ANDROID
  do create {HUAWEI} mine.make
    -- ST of mine is ANDROID; DT of mine is HUAWEI
    check attached {SMART_PHONE} mine as sp then ... end
    -- ST of sp is SMART_PHONE; DT of sp is HUAWEI
    check attached {HUAWEI} mine as huawei then ... end
    -- ST of huawei is HUAWEI; DT of huawei is HUAWEI
    check attached {SAMSUNG} mine as samsung then ... end
    -- Assertion violation
    -- ∵ SAMSUNG is not ancestor of mine's DT (HUAWEI)
    check attached {HUAWEI_P30_PRO} mine as p30_pro then ... end
    -- Assertion violation
    -- ∵ HUAWEI_P30_PRO is not ancestor of mine's DT (HUAWEI)
end
```

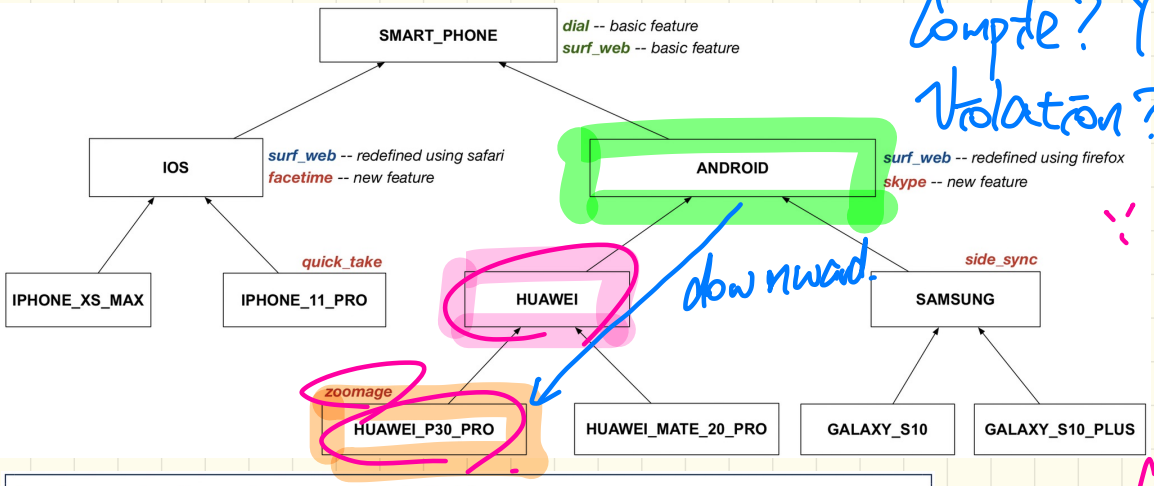
Cast Violation at Runtime (3)



Compile? YES. Downward-Violation? YES.
↓
∵ DT of mine (HUAWEI) cannot fulfil the cast type SAMSUNG's expec (e.g. side_sync)

```
test_smart_phone_type_cast_violation
  local mine: ANDROID
  do create {HUAWEI} mine.make
    -- ST of mine is ANDROID; DT of mine is HUAWEI
    check attached {SMART_PHONE} mine as sp then ... end
    -- ST of sp is SMART_PHONE; DT of sp is HUAWEI
    check attached {HUAWEI} mine as huawei then ... end
    -- ST of huawei is HUAWEI; DT of huawei is HUAWEI
    check attached {SAMSUNG} mine as samsung then ... end
    -- Assertion violation
    -- ∵ SAMSUNG is not ancestor of mine's DT (HUAWEI)
    check attached {HUAWEI_P30_PRO} mine as p30_pro then ... end
    -- Assertion violation
    -- ∵ HUAWEI_P30_PRO is not ancestor of mine's DT (HUAWEI)
end
```

Cast Violation at Runtime (4)



Compile? YES.
Violation? YES
∵ DT HUAWEI can't fulfill the last type HUAWEI_P30_PRO's exp. (zoomage).

```
test_smart_phone_type_cast_violation
  local mine: ANDROID
  do create {HUAWEI} mine.make
    -- ST of mine is ANDROID; DT of mine is HUAWEI
    check attached {SMART_PHONE} mine as sp then ... end
    -- ST of sp is SMART_PHONE; DT of sp is HUAWEI
    check attached {HUAWEI} mine as huawei then ... end
    -- ST of huawei is HUAWEI; DT of huawei is HUAWEI
    check attached {SAMSUNG} mine as samsung then ... end
    -- Assertion violation
    -- ∵ SAMSUNG is not ancestor of mine's DT (HUAWEI)
    check attached {HUAWEI_P30_PRO} mine as p30_pro then ... end
    -- Assertion violation
    -- ∵ HUAWEI_P30_PRO is not ancestor of mine's DT (HUAWEI)
end
```

Lecture 7

Part 10

Polymorphic Routine Arguments

Feature Call Parameters: Supplier

```
class STUDENT_MANAGEMENT_SYSTEM
  ss : ARRAY[STUDENT]
  add_s (s: STUDENT) do ss[0] := s end
  add_rs (rs: RESIDENT_STUDENT) do ss[0] := rs end
  add_nrs (nrs: NON_RESIDENT_STUDENT) do ss[0] := nrs end
```

Say:

sms: STUDENT_MANAGEMENT_SYSTEM

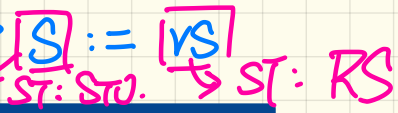
When should the following calls compile?

sms.add_s (o)

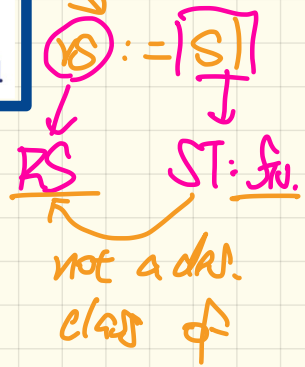
sms.add_rs (o)

sms.add_nrs (o)

Feature Call Arguments: Client




```
class STUDENT_MANAGEMENT_SYSTEM {
  ss : ARRAY[STUDENT] -- ss[i] has static type Student
  add_s (s: STUDENT) do ss[0] := s end
  add_rs (rs: RESIDENT_STUDENT) do ss[0] := rs end
  add_nrs (nrs: NON_RESIDENT_STUDENT) do ss[0] := nrs end
```




```
test_polymorphism_feature_arguments
  local
    s1, s2, s3: STUDENT
    rs: RESIDENT_STUDENT ; nrs: NON_RESIDENT_STUDENT
    sms: STUDENT_MANAGEMENT_SYSTEM
  do
    create sms.make
    create {STUDENT} s1.make ("s1")
    create {RESIDENT_STUDENT} s2.make ("s2")
    create {NON_RESIDENT_STUDENT} s3.make ("s3")
    create {RESIDENT_STUDENT} rs.make ("rs")
    create {NON_RESIDENT_STUDENT} nrs.make ("nrs")
```

not relevant to Jude compilation

sms.add_s (rs) ✓

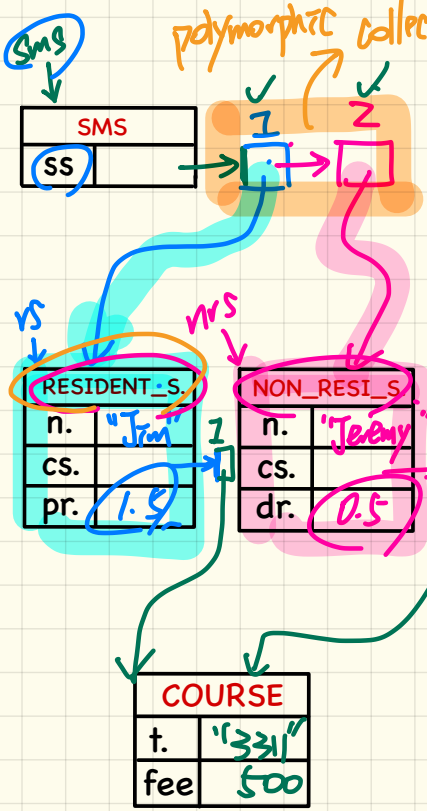
sms.add_rs (s1) ✗

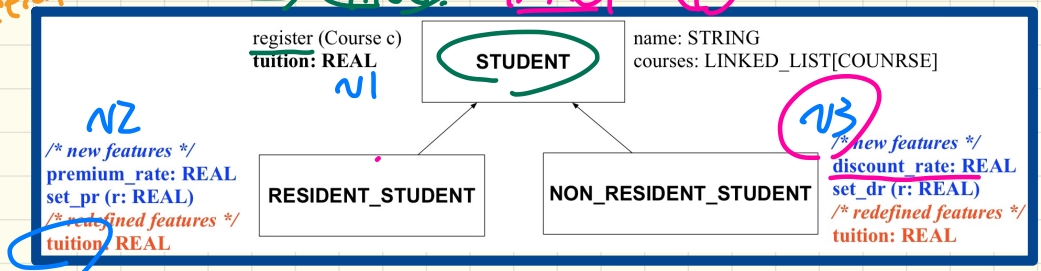
Lecture 7

Part 11

Polymorphic Collections

Polymorphic Collection






```
test_sms_polymorphism: BOOLEAN
  local
    rs: RESIDENT_STUDENT
    nrs: NON_RESIDENT_STUDENT
    c: COURSE
    sms: STUDENT_MANAGEMENT_SYSTEM
  do
    create rs.make ("Jim")
    rs.set_pr (1.5)
    create nrs.make ("Jeremy")
    nrs.set_dr (0.5)
    create sms.make
    sms.add_s (rs)
    sms.add_s (nrs)
    create c.make ("EECS3311", 500)
    sms.register_all (c)
    Result := sms.ss[1].tuition = 750 and sms.ss[2].tuition = 250
  end
```

```
class STUDENT_MANAGEMENT_SYSETM
  students: LINKED_LIST [STUDENT]
  add_student (s: STUDENT)
    do
      students.extend (s)
    end
  registerAll (c: COURSE)
    do
      across
        students as s
      loop
        s.item.register (c)
      end
    end
end
```

v2 of tuition

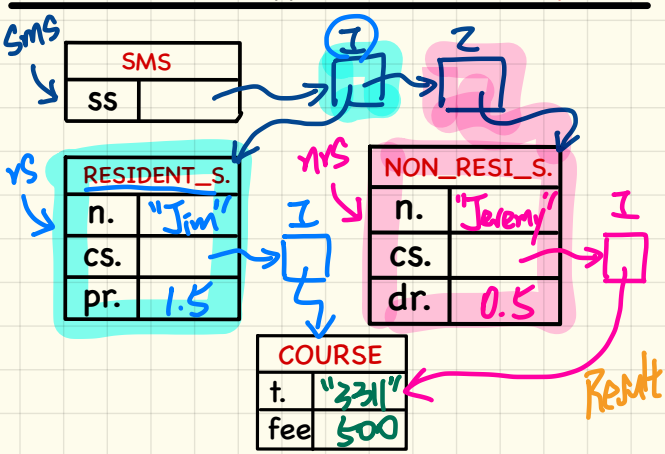
v3 of tuition

Lecture 7

Part 12

Polymorphic Return Values

Feature Call Return Values




```
class STUDENT_MANAGEMENT_SYSTEM {
  ss: LINKED_LIST[STUDENT]
  add_s (s: STUDENT)
    do
      ss.extend (s)
    end
  get_student(i: INTEGER): STUDENT
    require 1 <= i and i <= ss.count
    do
      Result := ss[i]
    end
end
```

```
test_sms_polymorphism: BOOLEAN
local
  rs: RESIDENT_STUDENT ; nrs: NON_RESIDENT_STUDENT
  c: COURSE ; sms: STUDENT_MANAGEMENT_SYSTEM
do
  create rs.make ("Jim") ; rs.set_pr (1.5)
  create nrs.make ("Jeremy") ; nrs.set_dr (0.5)
  create sms.make ; sms.add_s (rs) ; sms.add_s (nrs)
  create c.make ("EECS3311", 500) ; sms.register_all (c)
  Result :=
    sms.get_student(1).tuition = 750
    and get_student(2).tuition = 250
end
```

Possible DT of Result?