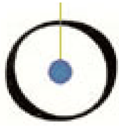
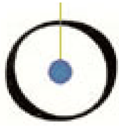


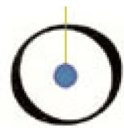
SCOOP

Simple Concurrent Object-Oriented Programming



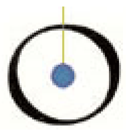
Lecture 4 (12):

Advanced OO mechanisms



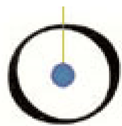
SCOOP and…

- Inheritance
- Genericity
- Agents
- Priorities
- Real-time
- Deadlocks

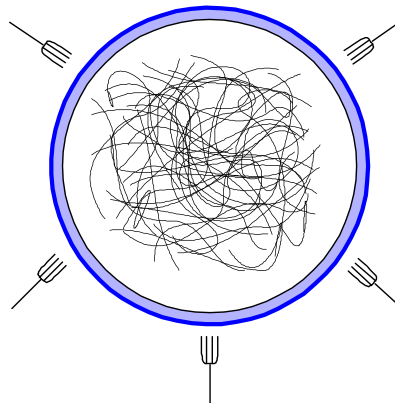


Inheritance

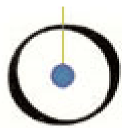
- Can we use inheritance as in the sequential world?
- Is multiple inheritance allowed?
- Does SCOOP suffer from inheritance anomalies?



Example: Dining philosophers

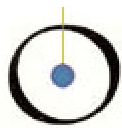


```
class PHILOSOPHER

inherit
    GENERAL_PHILOSOPHER
    PROCESS
        rename
            setup as getup
        undefine
            getup
        end

feature
    step is
                -- Perform a philosopher's tasks.
        do
            think
            eat (left, right)
        end

    eat (l, r: separate FORK) is
                -- Eat, having grabbed l and r.
        do
            ...
        end
end -- class PHILOSOPHER
```



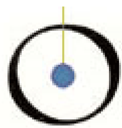
Class *PROCESS*


```
indexing
    description: "The most general notion of process"

deferred class PROCESS

feature -- Status report

    over: BOOLEAN is
            -- Should execution terminate now?
        deferred   end

feature -- Basic operations

    setup is
            -- Prepare to execute process operations (default: nothing).
        do   end

    step is
            -- Execute basic process operations.
        deferred   end
```



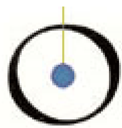
Class *PROCESS* (cont.)


```
    wrapup is
            -- Execute termination operations (default: nothing).
        do  end

feature -- Process behavior

    live is
            -- Perform process lifecycle.
        do
            from setup until over loop
                step
            end
            wrapup
        end

end -- class PROCESS
```



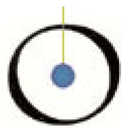
Class *GENERAL_PHILOSOPHER*


```
class
    GENERAL_PHILOSOPHER

create
    make

feature -- Initialization

    make (l, r: separate FORK) is
            -- Define l as left and r as right forks.
        do
            left := l
            right := r
        end

feature {NONE} -- Implementation

    left: separate FORK

    right: separate FORK
```



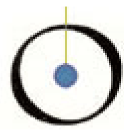
Class *GENERAL_PHILOSOPHER* (cont.)


```
getup is
        -- Take any necessary initialization action.
    do
    end

think is
        -- Any appropriate action or lack thereof
    do
    end

end -- class GENERAL_PHILOSOPHER


class
    FORK
end
```



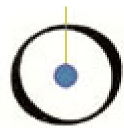
Inheritance

- Full support for inheritance (including multiple inheritance)
- Usual rules apply
  - Weakening pre-conditions
  - Strenghtening post-conditions
- Most inheritance anomalies eliminated thanks to the proper use of OO mechanisms
  - Thank you, Design by Contract!



Genericity

- Can we use genericity as in the sequential world?
- Is constrained genericity allowed?
- What is its impact on the type system?



Genericity

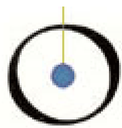
my_array: *ARRAY* [*X*]

my_array: **separate** *ARRAY* [*X*]

my_array: ARRAY [**separate** *X*]

my_array: **separate** *ARRAY* [**separate** *X*]

- Full support for genericity in SCOOP
  - Not fully implemented yet! ☹

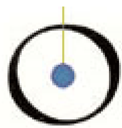


Constrained genericity: why

my_array: *ARRAY* [*X*]

my_array.item (2) < *my_array.item* (4)

- How do we know that operation “<” is defined for elements of *my_array*?



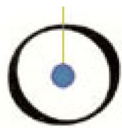
Constrained genericity: how

- We can declare class ARRAY as

  class *ARRAY* [*G* -> *COMPARABLE*]

- Class *COMPARABLE* implements operation “<”

- Only subtype of COMPARABLE can be actual generic parameter



Constrained genericity: how

- Only subtype of COMPARABLE can be actual generic parameter:

  my_array: *ARRAY* [*INTEGER*]

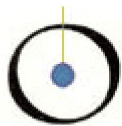
  my_array: *ARRAY* [*STRING*]

  but

  my_array: *ARRAY* [*ANY*]

  is invalid

- No restrictions on the use of constrained genericity in SCOOP



Genericity: impact on the type system

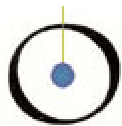
- If class is declared as

  class *ARRAY* [*G*]

  then its formal generic parameter is implicitely constrained to [*G* -> *ANY*]

  my_array: *ARRAY* [**separate** *STRING*] is invalid

  because **separate** *STRING* is not a subtype of *ANY*!



Genericity: impact on the type system

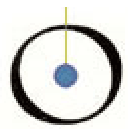
- To allow separate generic parameters, class has to be declared as

  class *ARRAY* [**separate** *G*]

  (then its formal generic parameter is implicitely constrained to [*G* -> **separate** *ANY*])

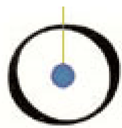
- If we want to constrain the formal generic parameter, we can declare the class as

  class *ARRAY* [G -> **separate** *HASHABLE*]



Agents

- What are agents?
- Don’t they cause trouble?
- How does SCOOP deal with them?
- Open issue: open arguments



What are agents?

- Agents represent routines ready to be called

  agent *x.f* is an "object wrapper" for *x.f*

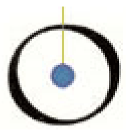
- We can use the agent as any other object, e.g. as source of assignment

  a: *PROCEDURE* [*ANY*, *TUPLE*]

  a := **agent** *x.f*

- We can also call the agent

  a.call this is equal to executing *x.f*



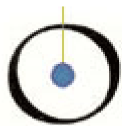
Open arguments

- We can fix arguments or leave them open

```
-- assume g is declared as
-- g (s: STRING; i: INTEGER)
a, b, c, d: PROCEDURE [ANY, TUPLE]
a := agent x.g ("Hello world", 5)
b := agent x.g (?, 5)
c := agent x.g ("Hello world", ?)
d := agent x.g (?, ?)
```

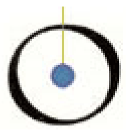
- Open arguments are set at call time

```
d.call (["Hello world", 5])
```



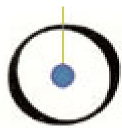
The trouble with agents


```
a: PROCEDURE [ANY, TUPLE]

store (buffer: separate BUFFER [INTEGER]; x: INTEGER ) is
    do
        buffer.put (x)
        a := agent buffer.put (?)        -- Valid!
        fishy_call (x)
    end

fishy_call (x: INTEGER) is
    do
        a.call ([x])    -- Valid! But a is a traitor!
    end
```



Solution: separate agents

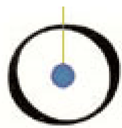

```
a: separate PROCEDURE [ANY, TUPLE]

store (buffer: separate BUFFER [INTEGER]; x: INTEGER ) is
    do
        buffer.put (x)
        a := agent buffer.put (?)        -- separate agent
        fishy_call (x)
    end

fishy_call (x: INTEGER) is
    do
        a.call ([x])    -- Invalid: a is not a formal argument.
    end
```



Separate agents


```
a: separate PROCEDURE [ANY, TUPLE]

store (buffer: separate BUFFER [INTEGER]; x: INTEGER ) is
    do
        buffer.put (x)
        a := agent buffer.put (?)
        not_so_fishy_call (a, x)
    end

not_so_fishy_call (an_agent: separate PROCEDURE [ANY, TUPLE];
                   x: INTEGER) is
    do
        an_agent.call ([x])     -- Valid: a is a formal argument.
    end
```

different semantics for argument passing: lock also *an_agent.target*



SCOOP and agents

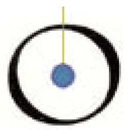
- Agents well integrated
- Open issue: open arguments
  - We cannot check statically that actual arguments conform to formal arguments expected by the agent
- Open-target agents are even trickier

  a: *PROCEDURE* [*ANY*, *TUPLE*]

  a := **agent** {*X*}.*f*

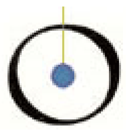
  a.call ([*x*]) -- equal to *x.f*

  a.call ([*y*]) -- equal to *y.f*



Priorities and real-time

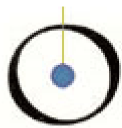
- How to satisfy VIP clients?
- The duel mechanism
- How to implement priority scheduling?
- How to provide other real-time capabilities?



SCOOP for real-time systems

- Possibility to execute the request of a VIP client while preempting the current client
  - Duels
  - Priorities

- Timing assertions
  - Maximal (and minimal) execution time
  - Timeouts on actions
  - Periodic and aperiodic activities



Duels

Can we snatch a shared object from its current holder?

- *holder* executes

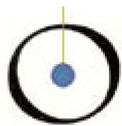
  holder.r (*b*) where *b* is **separate**

- another object *challenger* executes

  challenger.s (*c*) where *c*, also **separate**, is attached to the same object as the holder's *b*

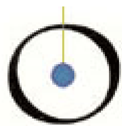
- Normally, the *challenger* will wait until the call to *r* is over

- What if the *challenger* is impatient?



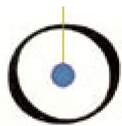
Semantics of duels

challenger → ↓ *holder*	*normal_service*	*demand*	*demand_if_ possible*
retain	*challenger* waits	exception in *challenger*	*challenger* waits
yield	*challenger* waits	exception in *Holder*	exception in *holder*



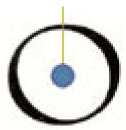
Semantics of duels with timeouts

challenger → ↓ *holder*	*normal_service*	*demand_with_ timeout (time)*	*demand_if_ possible_with_ timeout (time)*
retain	*challenger* waits	exception in *challenger*	*challenger* waits
yield	*challenger* waits	exception in *Holder*	exception in *holder*



Semantics of duels with timeouts

challenger → ↓ *holder*	*normal_service*	*demand_with_timeout (time)*	*demand_if_possible_with_timeout (time)*
retain_after_timeout (time)	*challenger* waits	exception in *challenger*	*challenger* waits
yield_after_timeout (time)	*challenger* waits	exception in *Holder*	exception in *holder*



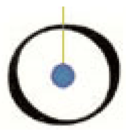
Extending duels with priorities

Tuning the duel mechanism:

- *holder*.*set_priority* (50)
- *challenger*.*set_priority* (100)
- *holder*.*yield*
- *challenger*.*demand*

If *challenger*.*priority* > *holder*.*priority* then

- *holder* will get an exception
- otherwise *challenger* will get an exception

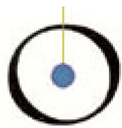


Priorities

- Extending *yield* to specific clients (e.g. *MOTOR*)
  For example *yield* ({*MOTOR*})

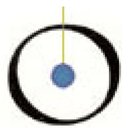
- *set_priority* (*i*: *INTEGER*)
  yield ({*MOTOR*}) can be mapped to priorities

- *yield* could even be mapped to a special case of priority.



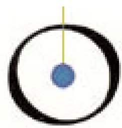
Timing in sequential programs


```
class
    TIMING_ASSERTION

feature  -- Access

    time_now: TIME
            -- The current time now.

    max_time_duration: TIME_DURATION
            -- Maximal time duration of a feature

    min_time_duration: TIME_DURATION
            -- Minimal time duration of a feature

end -- class TIMING_ASSERTION
```



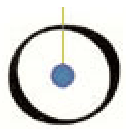
Timing in sequential programs (cont.)


```
class
    X
inherit
    TIMING_ASSERTION
        redefine
            default_create
        end

feature {NONE} – Creation

    default_create is
        do
            create min_time_duration.make_by_fine_seconds (0.05)
            create max_time_duration.make_by_fine_seconds (0.1)
        end
```



Timing in sequential programs (cont.)


```
feature

   f (a_time_started: TIME) is
      require
         a_time_started_not_void: a_time_started /= void
      do
               ...
         create time_now.make_now
      ensure
         minimal_execution_time:
         (time_now - a_time_started).duration > min_time_duration

         maximal_execution_time:
         (time_now - a_time_started).duration < max_time_duration
      end

end -- class X
```

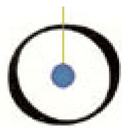


Deadlock and how to fight against it

- I hate deadlocks, I want to get rid of them!

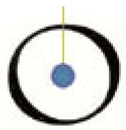
- Methods
  - Prevention
  - Avoidance
  - Detection
  - Resolution

- The SCOOP way



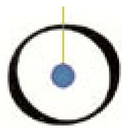
Deadlock prevention

- Check statically that no deadlocks can ever occur
- Difficult if we do not want to restrict programmers’ choices
- Needs smart compilers
- Example solution (simple but restrictive and not feasible in general)
  - impose total order on all shared resources and require them to be acquired in increasing order and released in decreasing order



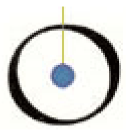
Deadlock avoidance

- Check at run-time that giving the task the access to a resource will not introduce any deadlock
- Needs smart scheduler
- Might be costly



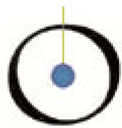
Deadlock detection

- Check at run-time whether a deadlock occurred
- Usually amounts to building a task/resource graph (Wait-For-Graph) and checking it for cycles
- Might be very costly, so it is better to avoid it
- Necessary in practice



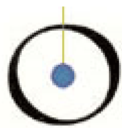
Deadlock resolution

- Happens at run-time when a deadlock is detected
- Usually done by the scheduler
- One of the tasks involved in the deadlock has to be preempted
- Problems
  - Choice of the right task to be killed
  - How to clean up the mess after that?



The SCOOP way

- Prevent
  - Compiler will be smart enough to issue a warning if there is potential deadlock (DbC needs to be extended)
  - Programmer has the choice to avoid the danger, e.g. by modifying the precondition of the concerned routine
  - Formal proof of deadlock freeness would also satisfy the compiler
- Detect (since programmer can decide in favour of run-time checks)
  - WFG searched for cycles
  - Daniel Moser's semester project
- Resolve
  - Pick a processor to preempt
  - Duels might help



How does SCOOP fit within the OO?

- Basic mechanism: feature call
- Design by Contract
  - Generalised semantics for preconditions, postconditions, and invariants
- Inheritance
  - No particular restrictions, usual rules apply
  - Most inheritance anomalies eliminated!
- Genericity: full support
- Agents: almost full support
  - Unclear semantics of agents with open target

That’s all, folks!

Questions?