Towards modelling and Verification of Concurrent Ada programs using Petri Nets

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Atomic Actions

- Structuring of complex concurrent systems
- Several action participants
- Synchronous or asynchronous entry
- Synchronous exit
- No flow across border during action
- System layering
- Complexity hiding

Error Recovery

- Indivisible units of execution
- All-or-nothing semantics
- Tolerance of software faults
- Backward error recovery
  – Restore previous state
- Forward error recovery
  – Exception handling

ADA features

- Packages
- Types
- Asynchronous transfer of control
- Protected types
- Requeue
- Exceptions
- Controlled types

Problems with ADA

- Model is very complex
- Even small examples have many states
- Need confidence in correctness
- Use Petri Nets to model concurrency
- Analyse using PN tools
  - PEP
  - INA
  - Design/CPN

ADA example

```
package simple_action is
  procedure T1(params : param); -- from Task 1
  procedure T2(params : param); -- from Task 2
  procedure T3(params : param); -- from Task 3
end simple_action;
```

```
with Ada.Exceptions; use Ada.Exceptions;
package body action is

  type Vote_T is (Commit, Aborted);
  protected controller is
    entry Wait_Abort(E: out Exception_Id);
    entry Done;
    entry Cleanup (Vote : Vote_t; Result : out Vote_t);
    procedure Signal_Abort(E: Exception_Id);
  private
    entry Wait_Cleanup(Vote : Vote_t; Result : out Vote_t);
    Killed : boolean := False;
    Releasing_cleanup : Boolean := False;
    Releasing_Done : Boolean := False;
    Reason : Exception_Id;
    Final_Result : Vote_t := Commit;
    informed : integer := 0;
  end controller;
```

```
protected body controller is
   entry Wait_Abort(E: out Exception_id) when killed is
   begin
     E := Reason;
     informed := informed + 1;
     if informed = 3 then
       Killed := False;
       informed := 0;
     end if;
   end Wait_Abort;
```

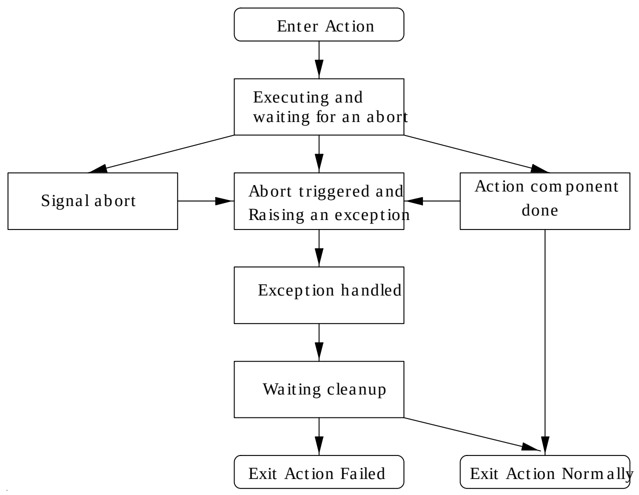
```
entry Done when Done'Count = 3 or Releasing_Done is
  begin
    if Done'Count > 0 then
      Releasing_Done := True;
    else
      Releasing_Done := False;
    end if;
  end done;

  entry Cleanup (Vote: Vote_t;
    Result: out Vote_t) when True is
  begin
    if Vote = aborted then
      Final_result := aborted;
    end if;
    requeue Wait_Cleanup with abort;
  end Cleanup;
```

```
procedure Signal_Abort(E: Exception_id) is
  begin
    killed := TRue;
    reason := E;
  end Signal_Abort;

  entry Wait_Cleanup (Vote : Vote_t; Result: out Vote_t)
      when Wait_Cleanup'Count = 3 or Releasing_Cleanup is
  begin
    Result := Final_Result;
    if Wait_Cleanup'Count > 0 then
      Releasing_Cleanup := True;
    else
      Releasing_Cleanup := False;
      Final_Result := Commit;
    end if;
  end Wait_Cleanup;
 end controller;
```

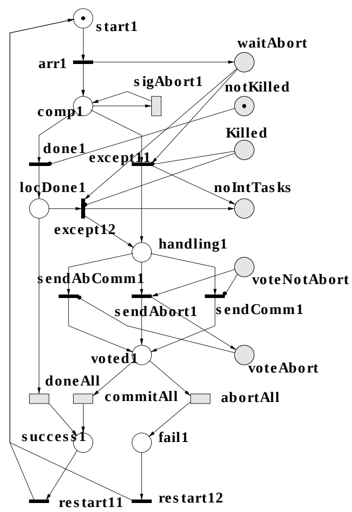
```
procedure T1(params: param) is
   X : Exception_ID;
   Decision : Vote_t;
 begin
   select
     Controller.Wait_Abort(X);
     raise_exception(X);
   then abort
     begin
       -- code to implement atomic action
       Controller.Done; --signal completion
     exception
       when E: others =>
         Controller.Signal_Abort (Exception_Identity(E));
     end;
   end select;
```

```
exception
    -- if any exception is raised during the action
    -- all tasks must participate in the recovery
    when E: others =>
      -- Exception_Identity(E) has been raised in all tasks
      -- handle exception
      if handled_ok then
        Controller.Cleanup(Commit, Decision);
      else
        Controller.Cleanup(Aborted, Decision);
      end if;
      if decision = aborted then
        raise atomic_action_failure;
      end if;
 end T1;

 -- similar for T2 and T3
end action;
```

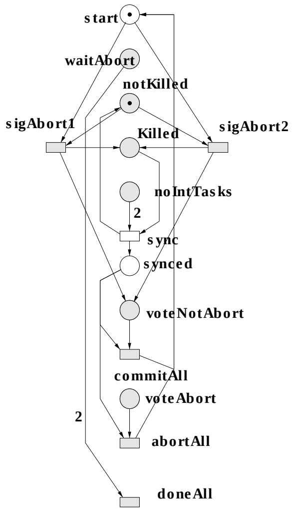
State diagram



Task Model



Controller model



Verification with PEP

success1,fail2
-- results in <NO>

Success1,success2
-- results in <YES>

Fail1,fail2
-- results in <YES>

Verification with INA

Safe - No

Bounded - Yes

Dead State Reachable - No

Covered by Transition-Invariants - Yes

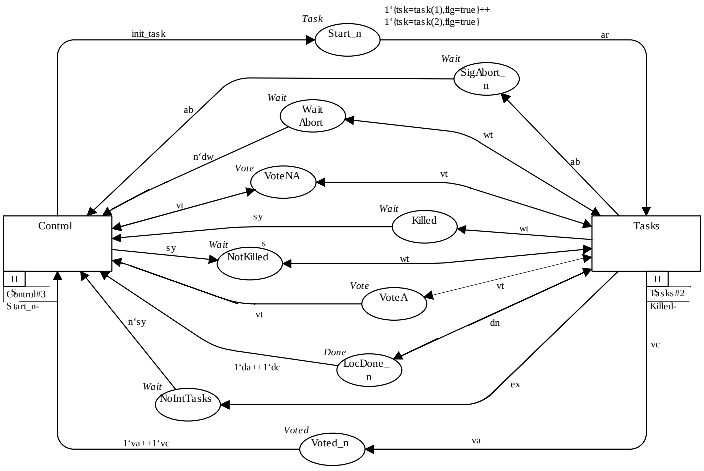
Resettable, reversable (to home state) - Yes

Dead transitions exist - No

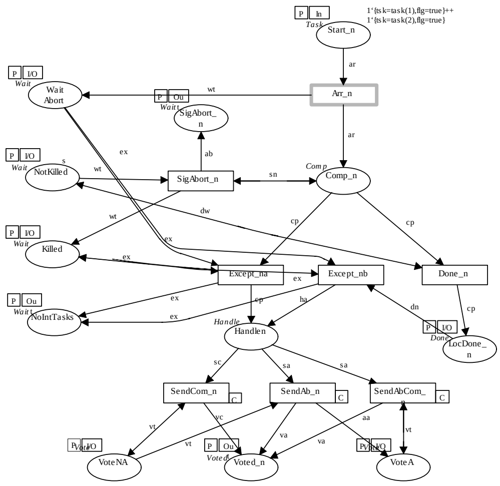
Live - Yes

Live and Safe - No

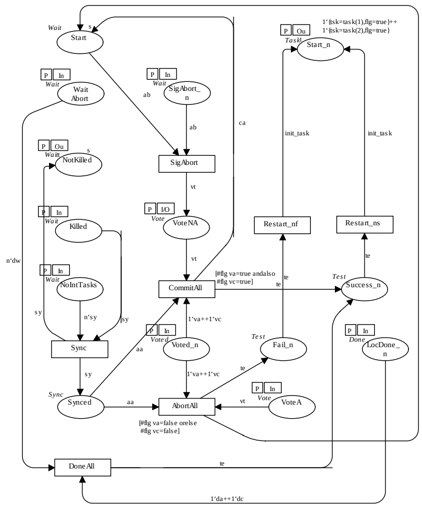
Verification with Design/CPN



Task model



Control model



Design/CPN: Statistics

Occurrence Graph		Scc Graph	
Nodes:	63	Nodes:	13
Arcs:	114	Arcs:	14
Secs:	0	Secs:	0
Status:	Full		

Design/CPN: Boundedness

Best Integers Bounds	Upper	Lower
Control'Fail_n 1	1	0
Control'Killed 1	1	0
Control'LocDone_n 1	2	0

Design/CPN: liveness

Dead Markings: None

Live Transitions Instances:

Control’AbortAll 1

Control’CommitAll 1

Control’Restart_nf 1

Control’Restart_ns 1

Control’SigAbort 1

Control’Sync 1

Control’AbortAll 1	Fair
Control’CommitAll 1	Fair
Control’DoneAll 1	Fair
Control’Restart_nf 1	Fair
Control’Restart_ns 1	Fair
Control’SigAbort 1	Fair
Control’Sync 1	Fair
Tasks’Arr_n 1	Impartial
Tasks’Done_n 1	Just

Conclusions

- Modelling and verification possible
- Improve confidence in correctness
- Hand translation only
- Need automated extraction
- No real-time issues yet