Verifying LTL properties of concurrent Ada programs with **Quasar**

ACM **SIGAda 2003**

S. Evangelista(*), C. Kaiser,
J-F Pradat-Peyre and P. Rousseau(*)

CEDRIC CNAM - Paris

December 10, 2003

Quasar Presentation (1/2)

- **Quasar Analyzes concurrent Ada programs**
- Method : **from source code to model**
- Based on the **Petri nets** formalism
- **Simple to use**
  - Automatic tool
  - No Petri nets knowledge required
  - Graphical interface

Quasar Presentation (2/2)

- Quasar proceeds in four steps :
  - **Slicing** : suppressing all the elements of the source code not related to the property to verify
  - **Translation** : translating the sliced source code into a Petri net
  - **Verification** : using structural and model-checking techniques to validate the property
  - Construction of a **report** : using counter-example and making the link between the formal model and the source code

Peterson Example (1/2)

```
task Type_T;
task body Type_T is
   My_Id : Id := 1;
begin
   loop
      Put_Line ("Before actions, task " & Id'Image (My_Id));
      Peterson.Enter (My_Id);
      Set_Controller_Instruction (My_Id);
      Peterson.Quit (My_Id);
      Put_Line ("After actions section , task " & Id'Image (My_Id));
   end loop;
end Type_T;

T_One : Type_T;
T_Two : Type_T;
```

Peterson Example (2/2)

```
Priority  : Id := 1;
Candidate : Tab_Candidate := (others => False);

procedure Enter (X : in Id) is
   Other : Id := (X mod 2) + 1;
begin
   Candidate (X) := True;
   Priority      := Other;
   while Condition_Not_Satisfied loop null; end loop;
end Enter;
```

Let us check three solutions

- not ((Candidate (X)) and (Priority = X))
- (Candidate (Other)) and (Priority = Other)
- (Candidate (Other)) or (Priority = Other)

First Step : Slicing

- Sliced program : without the colored lines

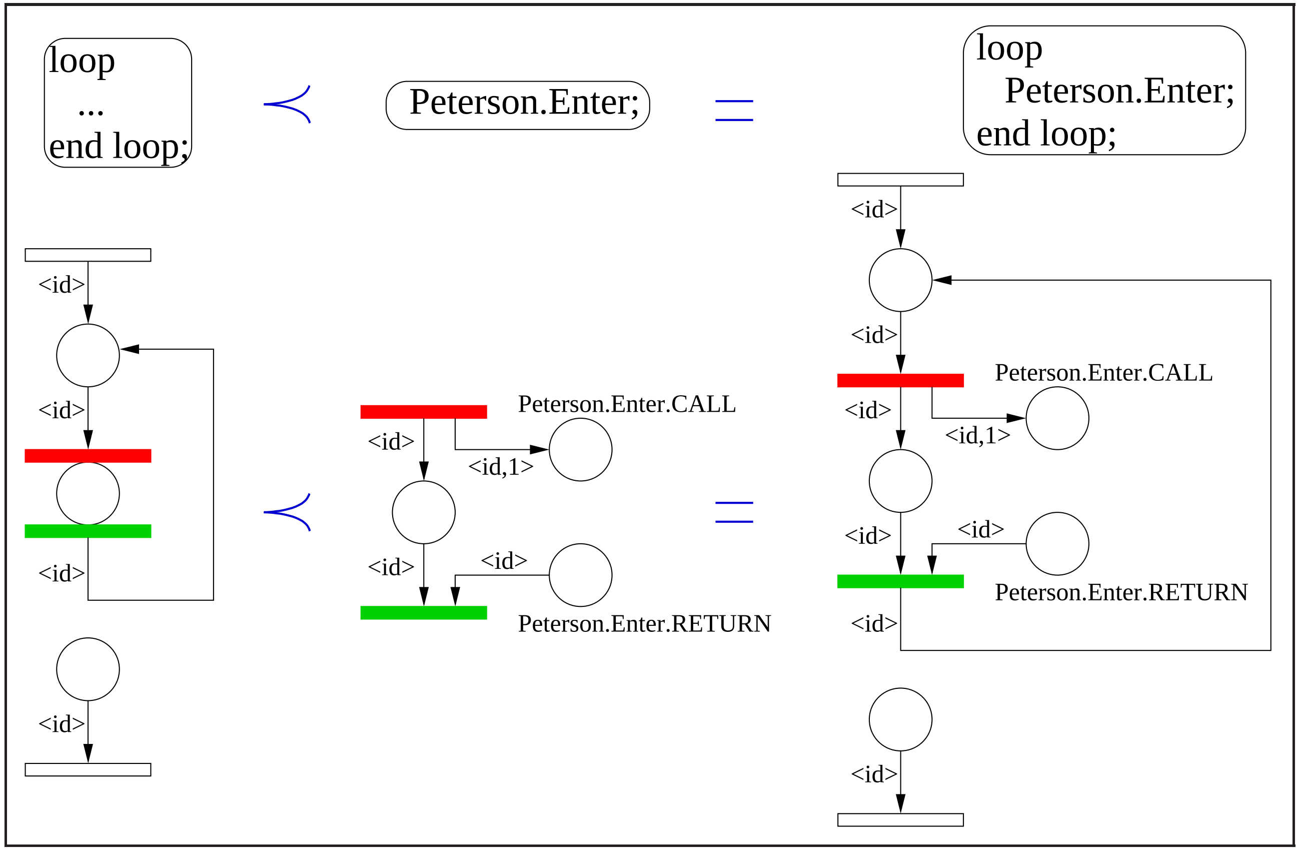
```
task Type_T;
task body Type_T is
   My_Id : Id := 1;
begin
   loop
      Put_Line ("Before actions, task " & Id'Image (My_Id));
      Peterson.Enter (My_Id);
      Set_Controller_Instruction (My_Id);
      Peterson.Quit (My_Id);
      Put_Line ("After actions section, task " & Id'Image (My_Id));
   end loop;
end Type_T;

T_One : Type_T;
T_Two : Type_T;
```

Second Step : Translation - Patterns

- Building the Petri net with components : **patterns**
  - **sub-net** : a partial Petri net corresponding to an element of the Ada language
  - **meta-net** : an abstraction of sub-net used to represent general part of an element (example : the statements of a loop)
- and with **operators** :
  - **Substitution** : replacing a meta-net by its corresponding sub-nets
  - **Merging** : merging two sub-nets

Second Step : Translation - Example

- Substitution example



Third Step : Verification - Process

- **Expressing the properties with a formal temporal logic**
  LTL (Linear Time Temporal Logic)
  - Atomic propositions
  - Propositional operators : $\neg$, $\wedge$, $\vee$
  - Temporal operators :
    U [until] (G [always], F [eventually]), X (next)
- **Verifying the properties** by model-checking

Third Step : Verification - Example

We want to verify the property :
"If the task T_One is candidate to enter in the critical section, T_One will access the critical section"

LTL $\rightarrow$ (T_One is Candidate) $\Rightarrow$ F (T_One is in CS)

LTL manipulation :

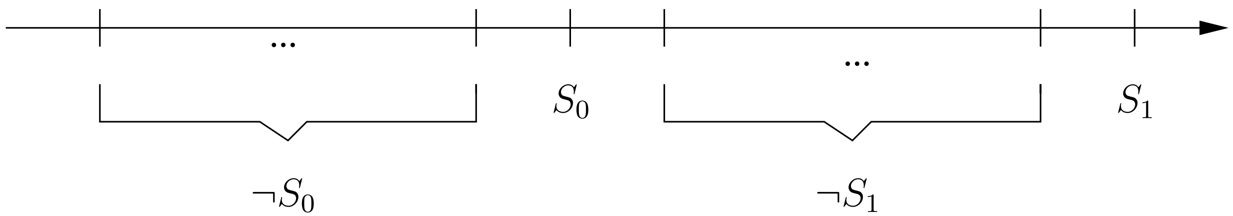
- **Not intuitive** and **error prone**
- Difficulty to make **reference to specific parts of the program**

Third Step : Verification - Our solution

- Using **templates** for simplifying LTL manipulation
  - Concerns **usual properties**
  - Keeps the **advantages of LTL** (precision and expressiveness)
  - Keeps the **advantages of automatization**

Third Step : Verification - Templates (1/2)

- State accessibility
  - **Inevitable state** : $\neg$ s$_0$ U (s$_0 \Rightarrow$ F s$_1$)



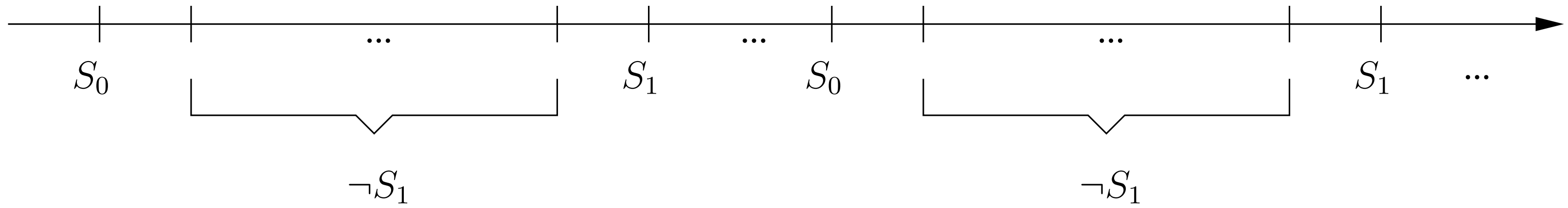
  - **Inevitable state with condition** :

    $\neg$ s$_0$ U (s$_0 \Rightarrow$ (Cond U F s$_1$))

  - **Home state** : $\neg$ s$_0$ U (s$_0 \Rightarrow$ G(F s$_1$))

Third Step : Verification - Templates (2/2)

- **Bounded Wait** : $G(s_0 \Rightarrow F\ s_1)$



- **Safety property** : $G(\neg\ s)$

- **Stability property** : $\neg\ f\ U\ G(f)$

- **Expert mode** : all LTL properties

Third Step : Verification - Program reference

- **Semi-graphical definition** of atomic properties based either on :
  - Value of variable
  - State of tasks (selected by line number)
  - ... still under development
    - Length of entry queues

Third Step : Verification - Example (cont.)

- Choice of the template → Bounded Wait : $G\ (s_0 \Rightarrow F\ s_1)$

  → s_0 : T_One is Candidate

  → s_1 : T_One is in CS

- Atomic proposition definition :
  - T_One is Candidate

    → value of a variable

    → (Candidate(1) = True)
  - T_One is in CS

    → Selection of a task variable and task body line

    → T_One@8

Fourth Step : Report

- Automatic **detection of the sequence leading to the error**
- Step by step **graphical representation** of this sequence
- Programmers can **understand easily** the design error using the generated trace
- **Correction** and new check of the program

Quasar allows us to verify that the second solution of Peterson example is the only valid one

Conclusion

- An easy way to **add verification of LTL properties** in **Quasar** **using templates**
- Future works
  - Extending **coverage of the language** (pointers, dynamic tasking, objects, ...)
  - Extending temporal properties to Computational Tree Logic (**CTL**)
  - **Improving** specific verification techniques
    - **Structural techniques** with colored Petri nets reductions
    - **Model-checking** using the knowledge of the generated Petri nets structure