Verifying SimpleGT Transformations Using an Intermediate Verification Language

Zheng Cheng, Rosemary Monahan, James F. Power

Computer Science Department, Maynooth University, Ireland

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Model Driven Engineering (MDE) and Model Transformation

Model transformation is an important ingredient in MDE.

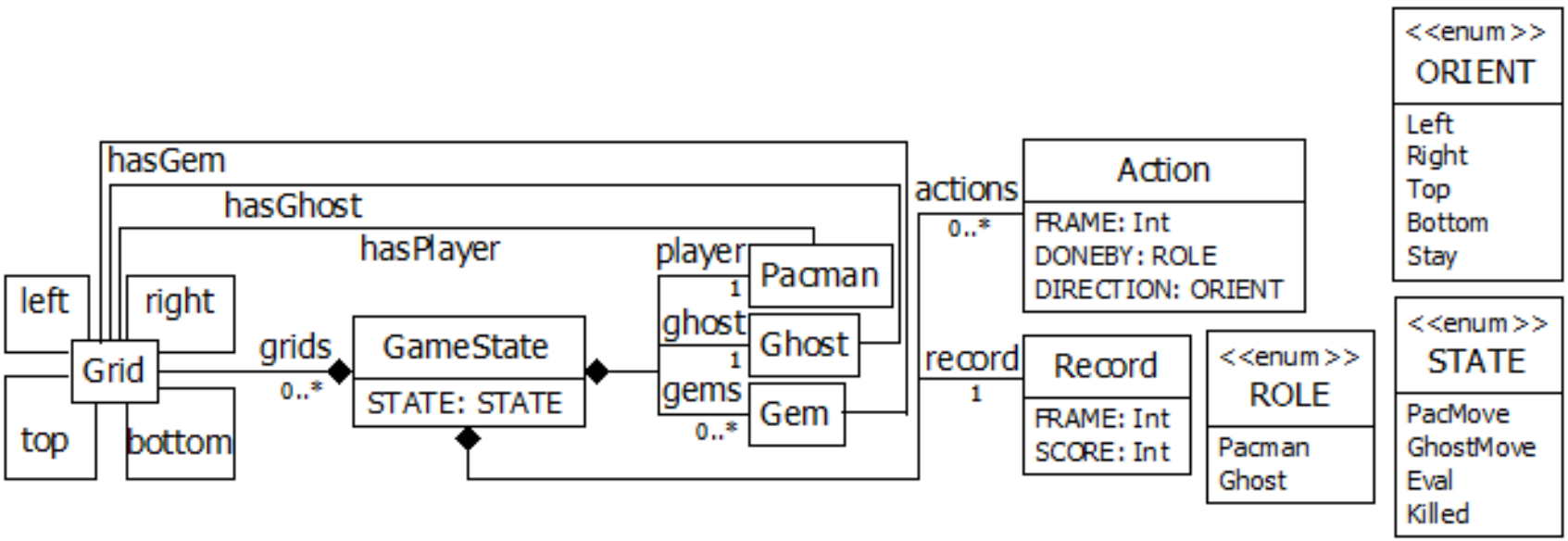
- Operational model transformation, e.g. Kermeta, QVTo.
- Relational model transformation, e.g. ATL, ETL.
- Graph model transformation (GT), e.g. SimpleGT, Henshin.

Model Driven Engineering (MDE) and Model Transformation

Proving the correctness of SimpleGT.

- "Correctness" means assumptions about the GT, given as **contracts**.
- GT is well suited to describe scenarios such as distributed systems or behaviours of structure-changing systems (e.g. mobile networks).

Pacman Metamodel (Syriani and Vangheluwe, 2013)



SimpleGT Transformation

```
rule PlayerMoveLeft{
   from
      s:P!GameState(STATE=~PacMove,record=~rec), rec:P!Record,
      pac:P!Pacman,
      grid2:P!Grid, grid1:P!Grid(hasPlayer=~pac,left=~grid2),
      act:P!Action(DONEBY=~Pacman,FRAME=~rec.FRAME,DIRECTION=~Left)
   not grid2: P!Grid(hasEnemy=~ghost), ghost: P!Ghost
   to
      s:P!GameState(STATE=~GhostMove,record=~rec), rec:P!Record,
      pac:P!Pacman,
      grid2:P!Grid(hasPlayer=~pac), grid1:P!Grid(left=~grid2) } ...
```

OCL Contracts

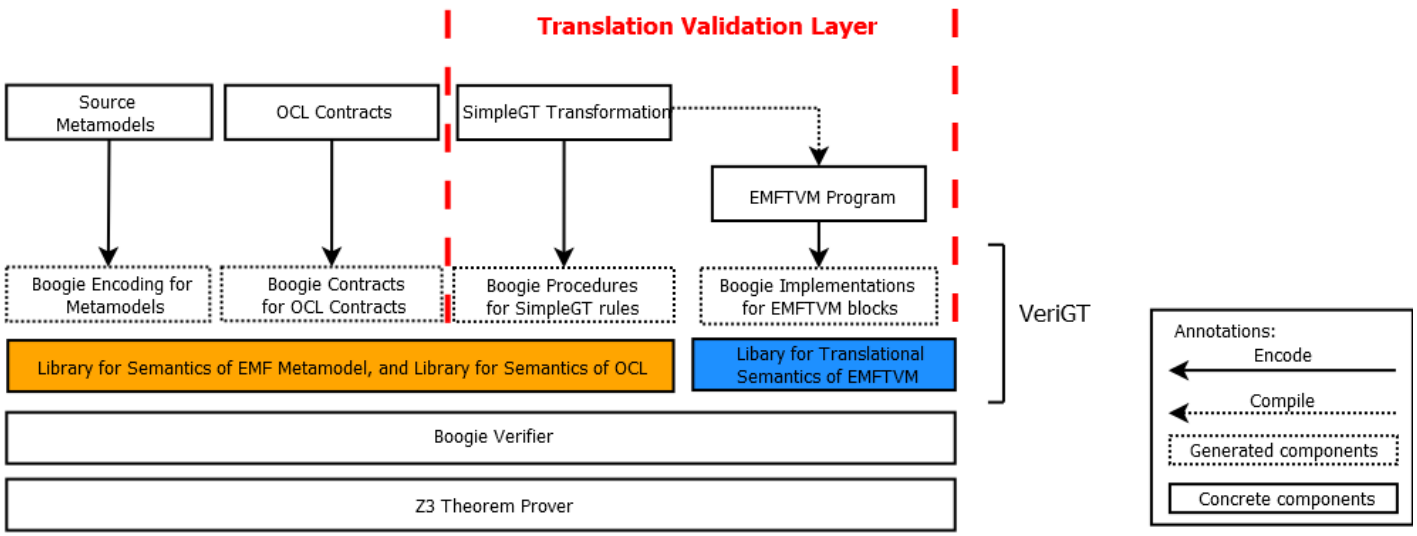
```
... -- well-formatness contracts of the Pacman game.

-- all grids containing a gem must be reachable by Pacman.
context Grid inv gemReachable:
  Grid.allInstances()->forall(g1,g2:Grid|not g1.hasPlayer.isOclUndefined()
    and not g2.hasGem.isOclUndefined() implies reachable(g1,g2))

-- exists a path where the ghost never kills Pacman.
context GameState inv PacmanSurvive:
  self.STATE==GhostMove implies self.grids->forall(
    g1:Grid|g1.hasEnemy.oclIsKindOf(Ghost) implies
      not g1.hasPlayer.oclIsKindOf(Pacman))

-- the Pacman must move within a time interval I.
context Action inv PacmanMoved:
  let col:Sequence=Action.allInstances()->select(
    a:Action|a.DONEBY=Pacman and not a.Direction=Stay)->asSequence() in
      col->forall(i:int|0<=i<col->size()-1 implies
        col->at(i+1).FRAME-col->at(i).FRAME<=I)
```

Objective of Our Research

Design a deductive verifier for the SimpleGT language, which enables its formal verification.

- Investigate whether the Boogie intermediate verification language (IVL) can be used to systematically designing modular and reusable verifiers.
- Investigate whether the translation validation approach from compiler verification can be automated to ensure the soundness of the verification [Cheng et al. 2015].

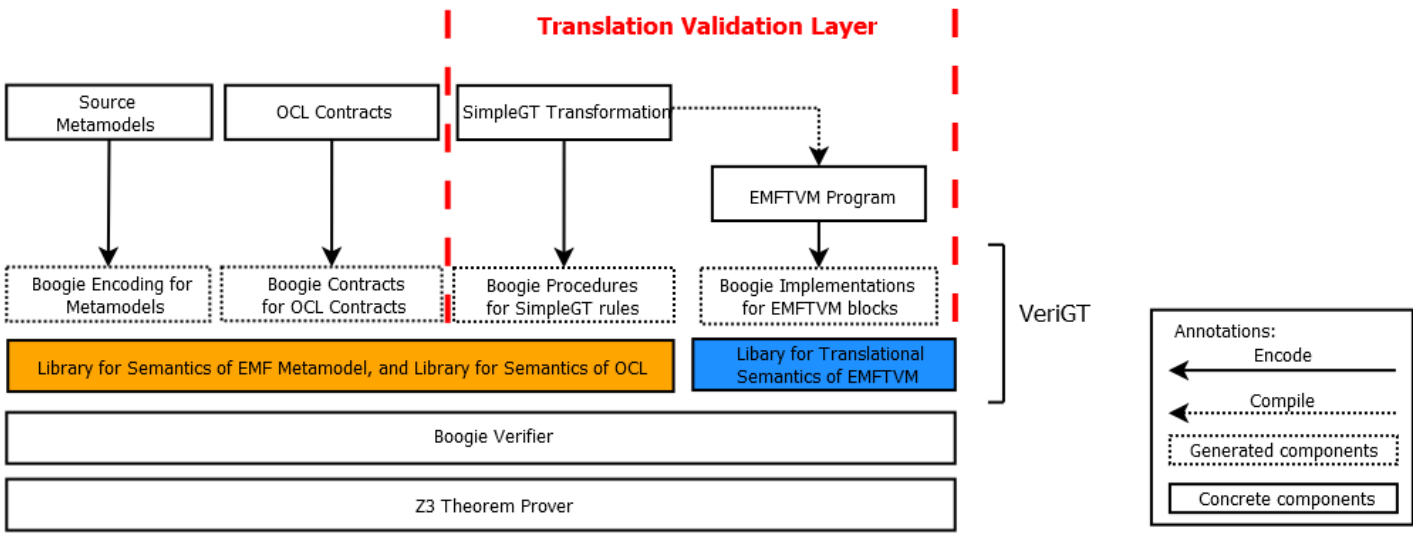
Bird's Eye View of VeriGT



Introduction to Boogie

```
1   procedure McCarthy(n: int);
2     returns (r: int)
3     ensures 100 < n ⟹ r = n − 10;
4     ensures n ≤ 100 ⟹ r = 91;
5
6   implementation McCarthy(n: int);
7   {
8     if (100 < n) {
9       r := n − 10;
10    } else {
11      call r := F(n + 11);
12      call r := F(r);
13    }
14  }
```

Bird's Eye View of VeriGT



Example: SimpleGT Rule

```
rule PlayerMoveLeft{
   from
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      pac:P!Pacman,
      grid2:P!Grid, grid1:P!Grid(hasPlayer=~pac,left=~grid2),
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   not grid2: P!Grid(hasEnemy=~ghost), ghost: P!Ghost
   to
      s:P!GameState(STATE=~GhostMove,record=~rec), rec:P!Record,
      pac:P!Pacman,
      grid2:P!Grid(hasPlayer=~pac), grid1:P!Grid(left=~grid2) } ...
```
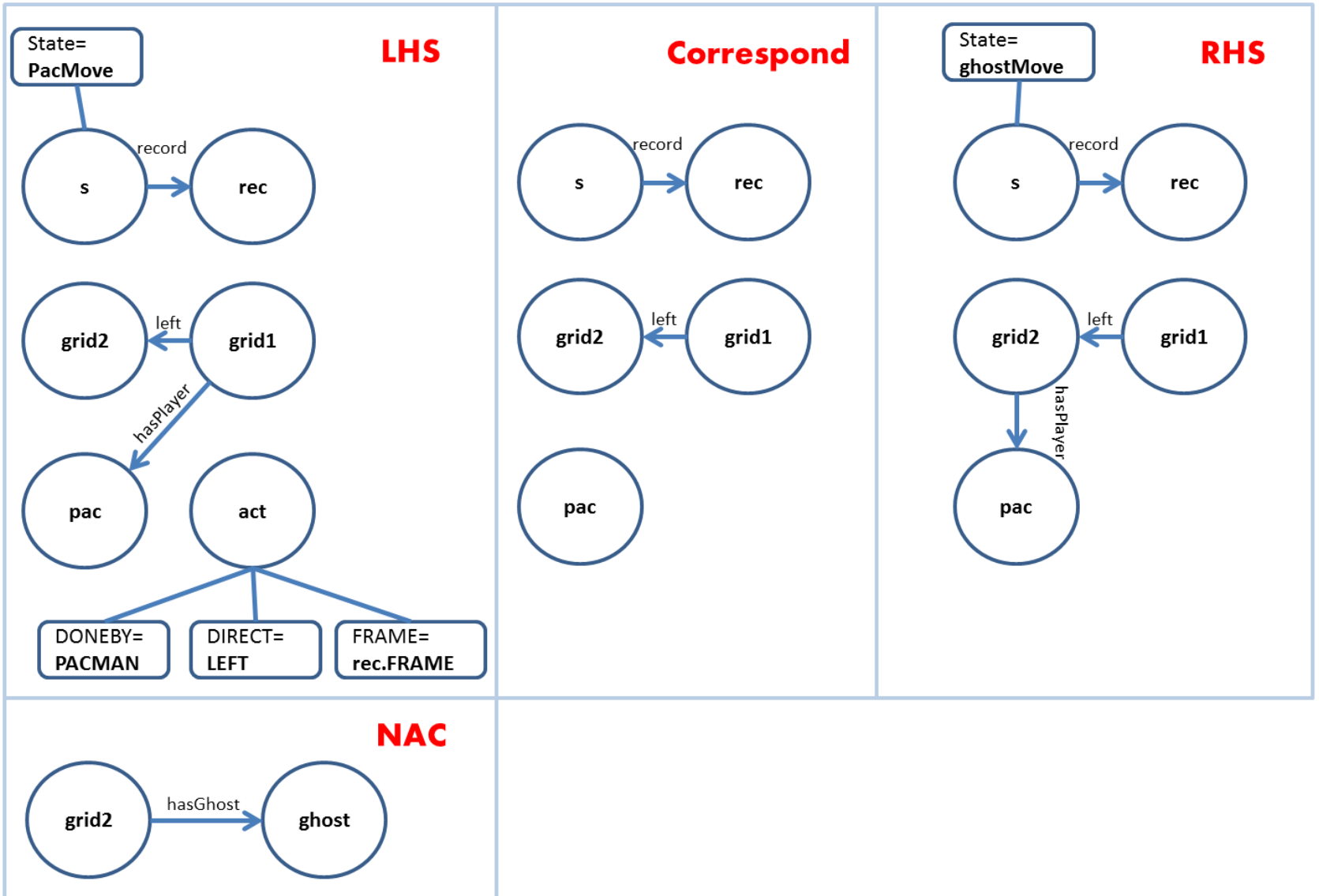
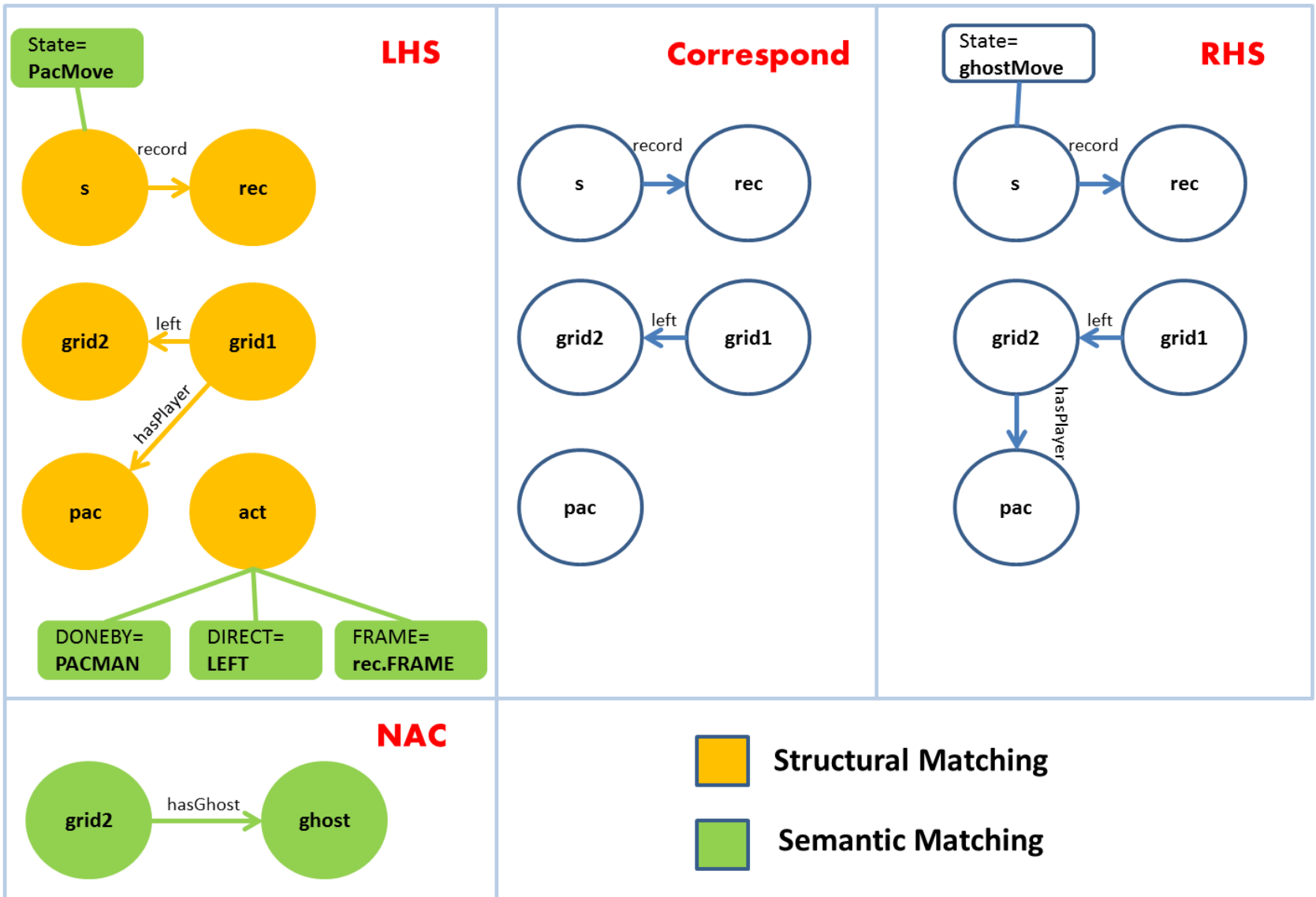

Example: SimpleGT Rule (a Graphical Representation)

PacmanMoveLeft:



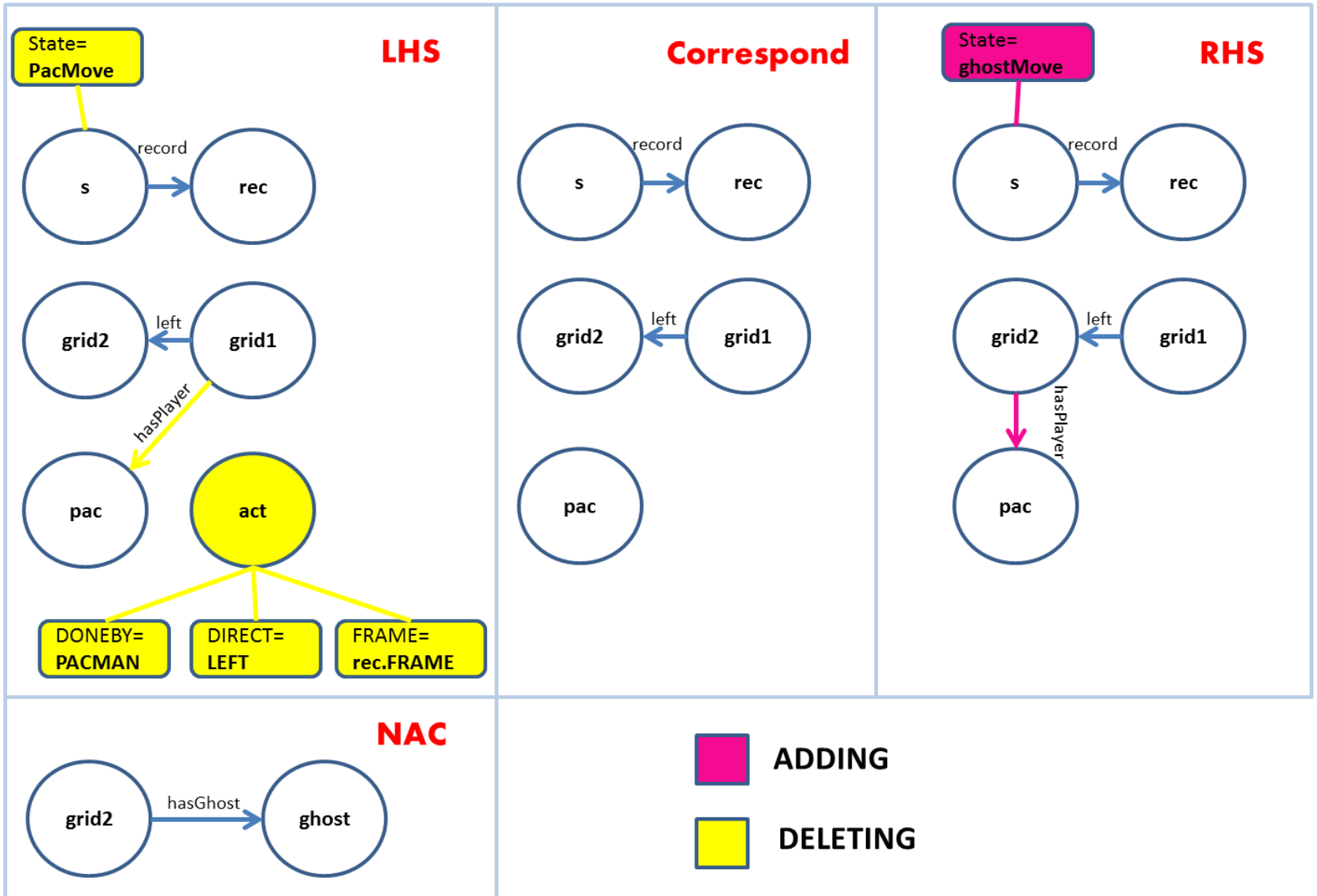
Example: SimpleGT Rule (Match)

PacmanMoveLeft (match step):

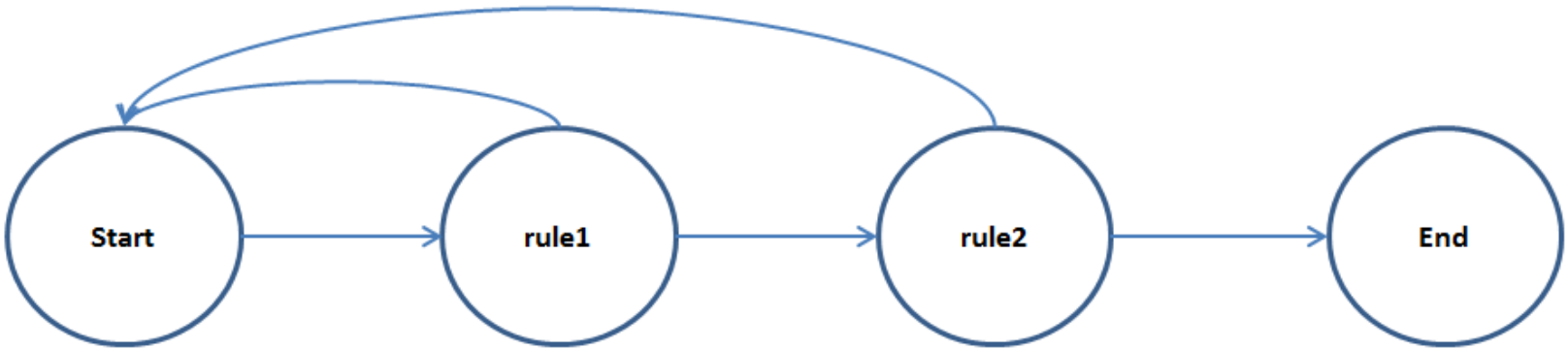


Example: SimpleGT Rule (Apply)

PacmanMoveLeft (apply step):

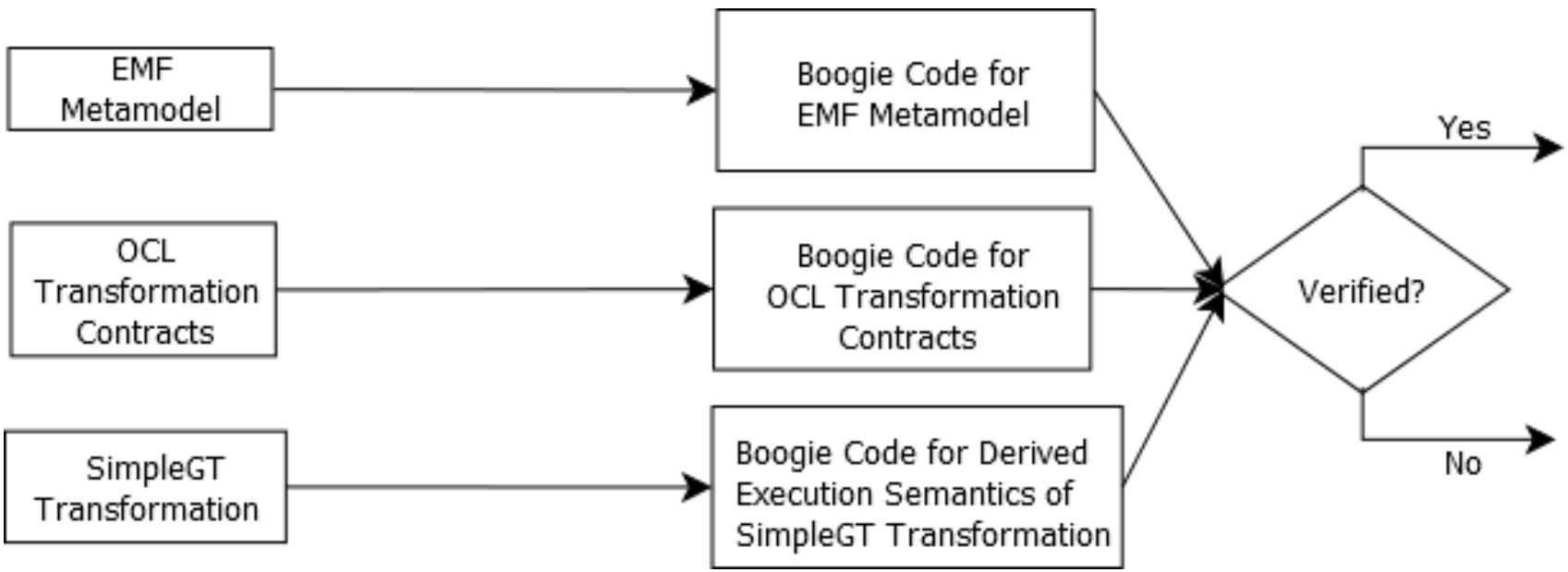


Rule Scheduling



- After each application, the rule scheduling restarts immediately.
- If there is no match for the first rule, it falls-off to match the second rule.

VeriGT in Action



Evaluation

	Boogie (LoC)	Veri. Time (s)
gemReachable	421	0.998
PacmanSurvive	467	1.747
PacmanMoved	439	0.109
Total	1327	2.854

Related Work

- Theorem proving (Unbounded) vs. Simulation/Model Checking/Model Finding (Bounded).
- The soundness of GT verification approaches based on theorem proving.
- Intermediate verification languages, e.g. Why3, Boogie.

Future Work

- Mature implementation of VeriGT integrated with Eclipse.
- Termination verification with VeriGT.

Q & A

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{zcheng,rosemary,jpower}@cs.nuim.ie

https://github.com/VeriATL/VeriGT