Formalizing Design Patterns:
A Comprehensive Contract for Composite

Jason O. Hallstrom
School of Computing, CS Division
Clemson University

Neelam Soundarajan
Computer Science and Engineering
Ohio State University

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Responsibilities and Rewards

When using a pattern in an given application, designers are interested in two sets of properties

- Responsibilities
  The implementation requirements that must be satisfied to apply the pattern correctly
- Rewards
  The system properties that result by virtue of satisfying the implementation requirements

A comprehensive pattern formalism must capture both

The Formalization Challenge

The main challenge in formalizing patterns is striking the right balance between two competing objectives

- ❖ Precision
  Implementation requirements and behavioral guarantees must be clear and unambiguous
- ❖ Flexibility
  Pattern specifications must be customizable as appropriate to particular applications

A comprehensive pattern formalism must satisfy both

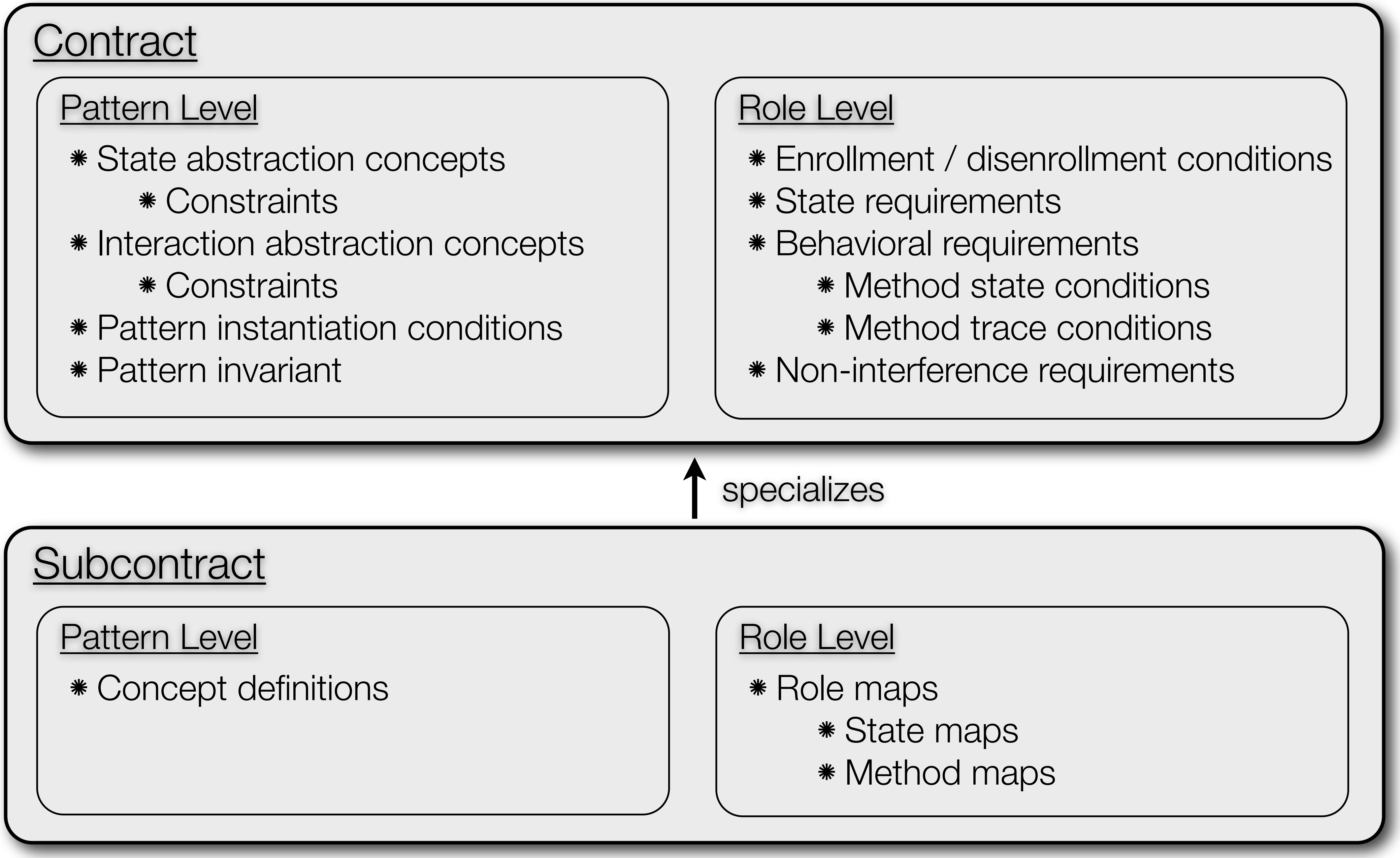
Pattern Contracts

Our approach to addressing these requirements relies on a multi-level contract framework

- Pattern Contract
  Captures the requirements and guarantees associated with *all* instances of a given pattern
- Pattern Subcontract
  Refines a pattern contract (or subcontract) to yield the specification of a sub-pattern or pattern implementation

Abstraction concepts are a key source of contract flexibility

Contract Structure



Contract

Pattern Level

- State abstraction concepts
    - Constraints
- Interaction abstraction concepts
    - Constraints
- Pattern instantiation conditions
- Pattern invariant

Role Level

- Enrollment / disenrollment conditions
- State requirements
- Behavioral requirements
    - Method state conditions
    - Method trace conditions
- Non-interference requirements

specializes

Subcontract

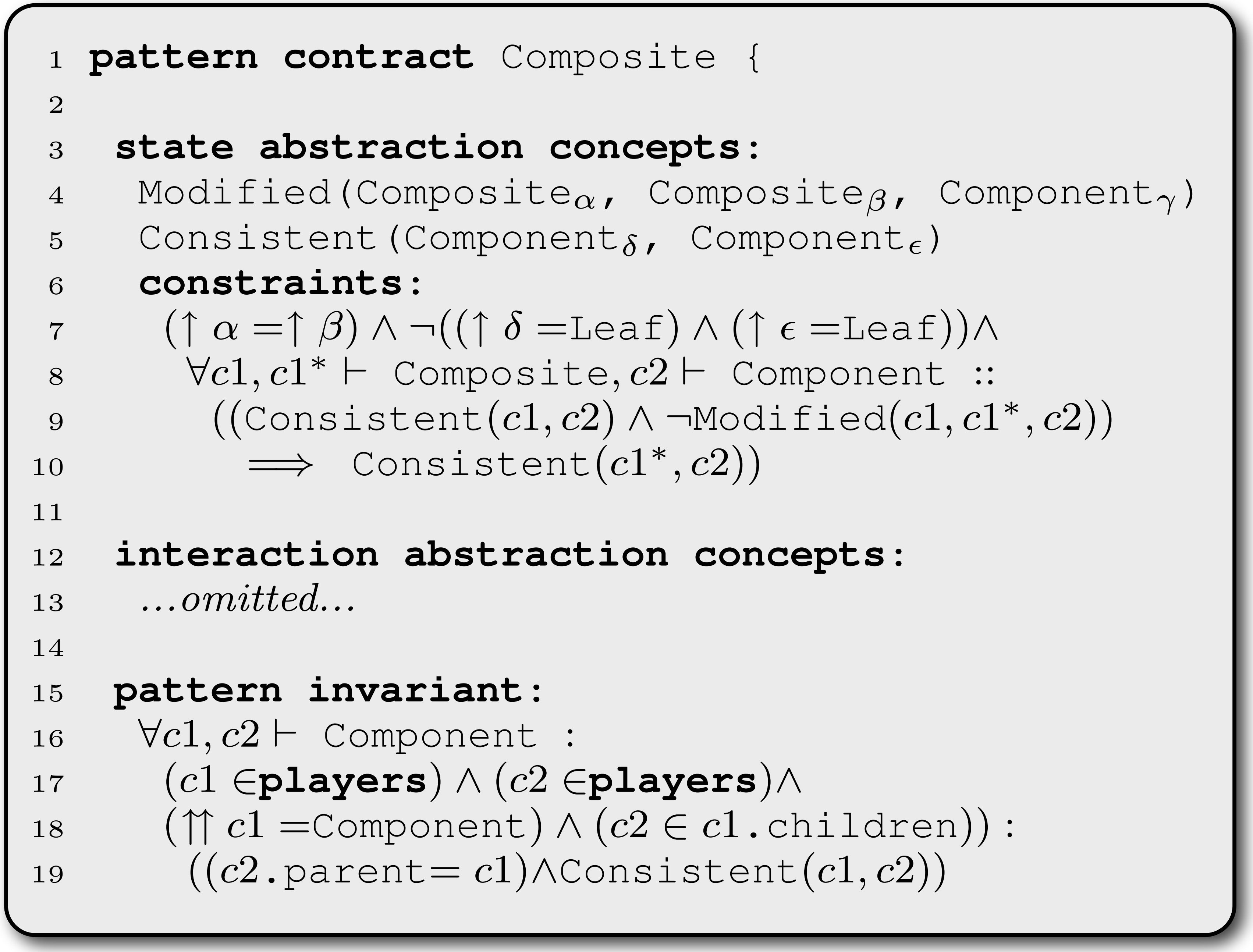
Pattern Level

- Concept definitions

Role Level

- Role maps
    - State maps
    - Method maps

Example: Composite Pattern (1/3)



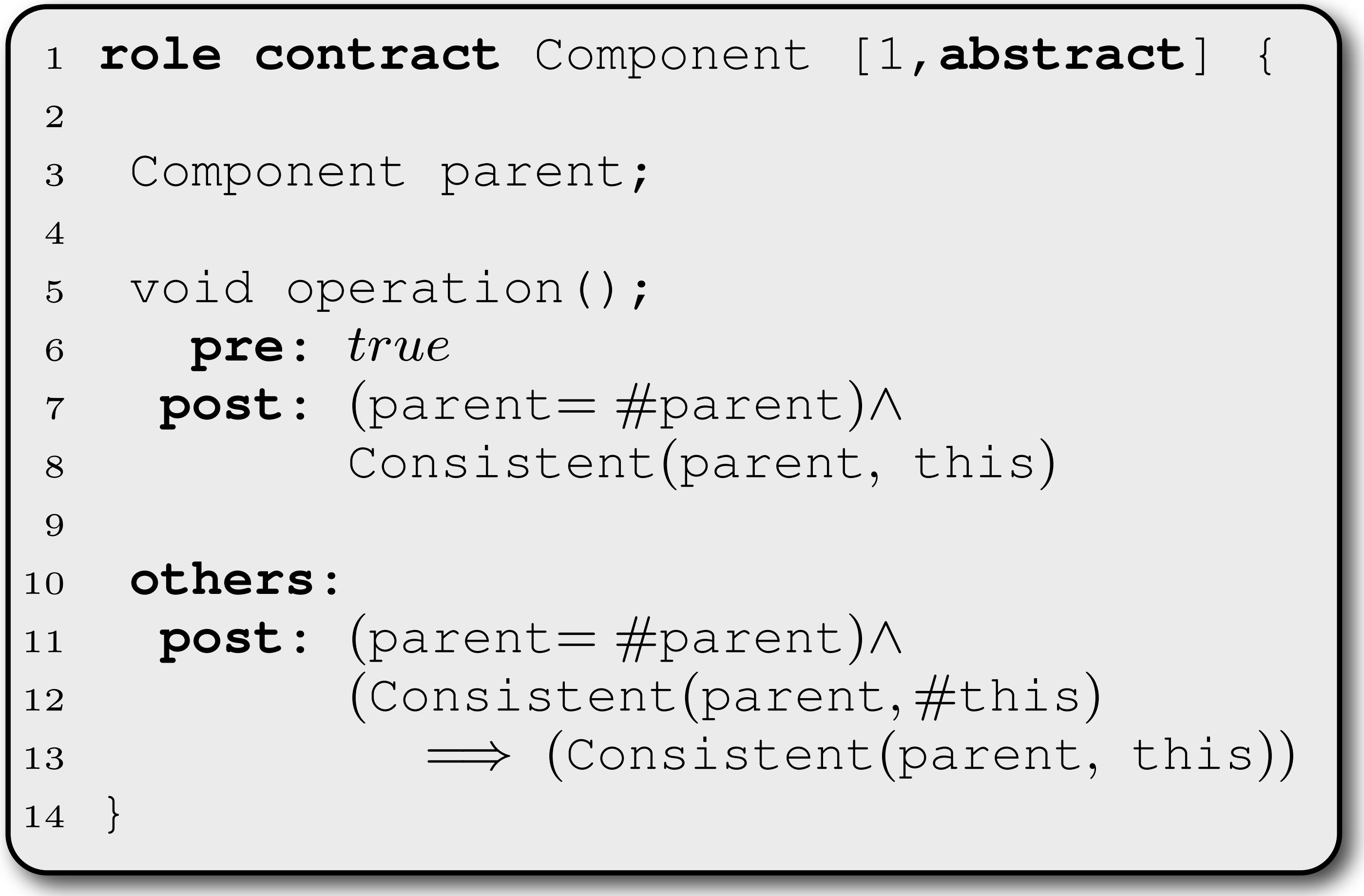
```
pattern contract Composite {

 state abstraction concepts:
  Modified(Composite$_\alpha$, Composite$_\beta$, Component$_\gamma$)
  Consistent(Component$_\delta$, Component$_\epsilon$)
  constraints:
   $(\uparrow \alpha =\uparrow \beta) \land \neg((\uparrow \delta =$Leaf$) \land (\uparrow \epsilon =$Leaf$))\land$
    $\forall c1, c1^* \vdash$ Composite, $c2 \vdash$ Component ::
     $(($Consistent$(c1, c2) \land \neg$Modified$(c1, c1^*, c2))$
      $\implies$ Consistent$(c1^*, c2))$

 interaction abstraction concepts:
  $\ldots$omitted$\ldots$

 pattern invariant:
  $\forall c1, c2 \vdash$ Component :
   $(c1 \in$players$) \land (c2 \in$players$)\land$
   $(\uparrow\uparrow c1 =$Component$) \land (c2 \in c1$.children$))$ :
    $((c2$.parent$= c1)\land$Consistent$(c1, c2))$
```

Example: Composite Pattern (2/3)

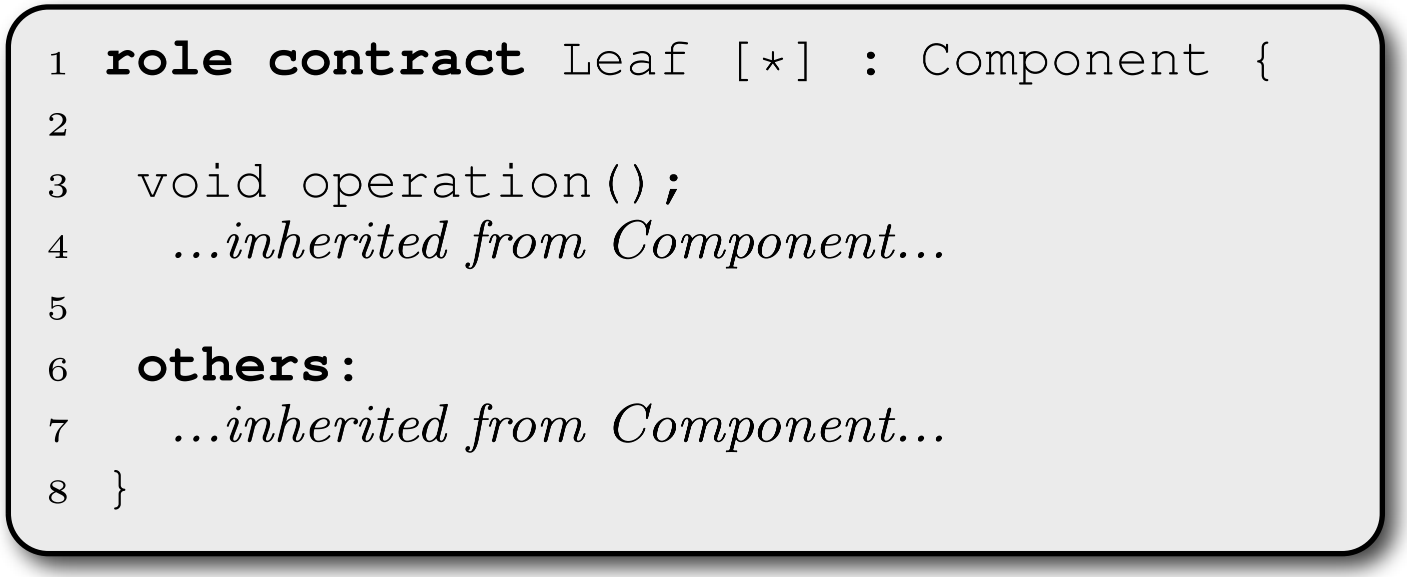


```
role contract Component [1,abstract] {

 Component parent;

 void operation();
   pre: true
  post: (parent= #parent)∧
        Consistent(parent, this)

 others:
  post: (parent= #parent)∧
        (Consistent(parent,#this)
           ⟹ (Consistent(parent, this))
}
```



```
role contract Leaf [⋆] : Component {

 void operation();
  ...inherited from Component...

 others:
  ...inherited from Component...
}
```

Example: Composite Pattern (3/3)

```
role contract Composite [+] : Component {

 Set<Component> children;

 void add(Component c);
   pre: c ∉ children
  post: (children= (#children∪{c}))∧
        (c.parent=this)∧
         ∀oc ⊢ Component :
          (oc ∈ #children):
           ¬Modified(this, #this, oc)∧
        (|τ.c.operation| = 1)

 void remove(Component c);
   pre: c ∈ children
  post: (children= (#children−{c}))∧
        ∀oc ⊢ Component :
         (oc ∈ #children):
          ¬Modified(this, #this, oc)

 ...other child management methods omited...

```

```
 void operation();
   pre: ...inherited from Component...
  post: ...inherited from Component...∧
        (children= #children)∧
        ∀c ⊢ Component :
         (c ∈children):
          (Modified(this, #this, c)
           ⟹ (|τ.c.operation| = 1))

 others:
   ...inherited from Component...∧
   (children=children)∧
   ∀c ⊢ Component :
    (c ∈ #children):
     ¬Modified(this, #this, c)
}
```

Questions?

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