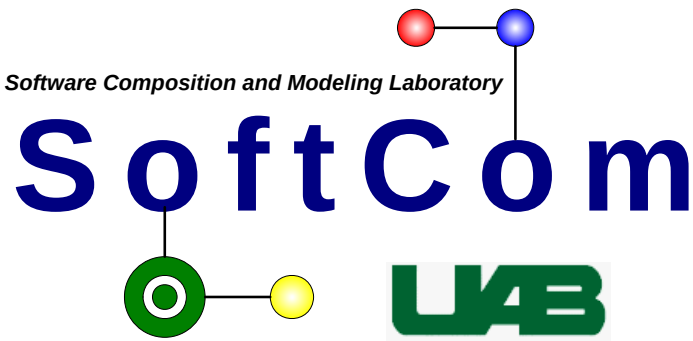
CoCloRep: A DSL for Code Clones

Robert Tairas

with Shih-Hsi Liu, Frédéric Jouault, and Jeff Gray



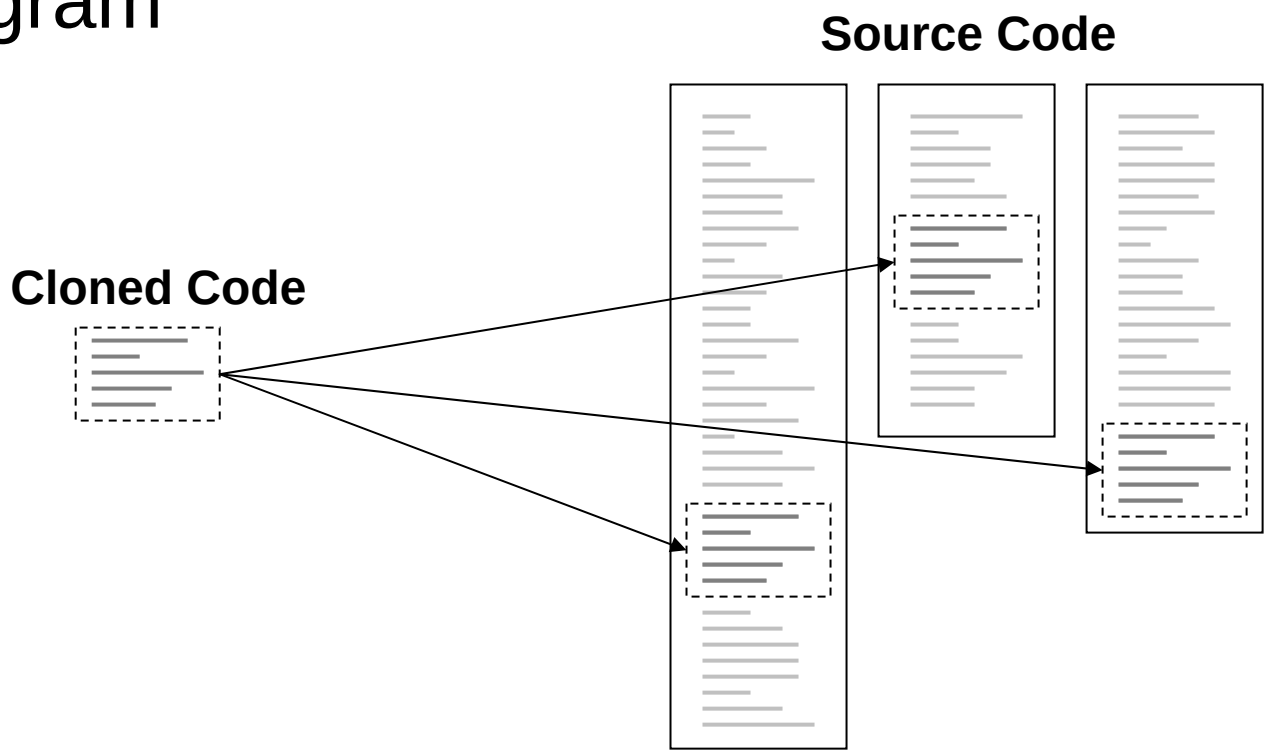
Department of Computer and Information Sciences
University of Alabama at Birmingham

Workshop on Software Language Engineering
MoDELS 2007, Nashville, TN

This project is supported by
NSF grant CPA-0702764 and the OpenEmbeDD project

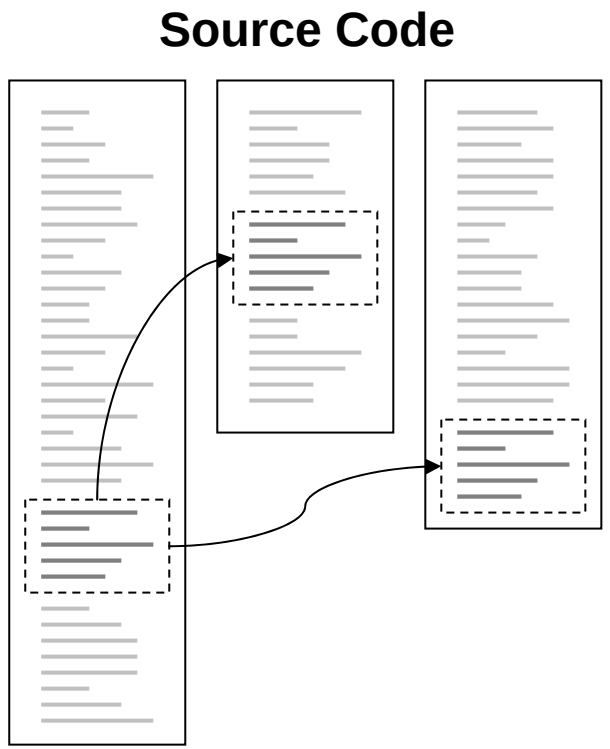
Code Clones

- Code clone: a sequence of statements that are duplicated at multiple locations in a program



Clones in Source Code

- Origin: copy-and-paste parts of code from one location to another
  - The copied code already works correctly
  - No time to be efficient
- Research shows that 6-8% of large-scale application code are clones (Jiang, 2006)



Background: Clone Detection Tools

- String
  - (Johnson, 1994), (Ducasse, 1999)
- Token
  - Dup (Baker, 1996), CCFinder (Kamiya, 2002), (Basit, 2007)
- Abstract Syntax Tree
  - CloneDR (Baxter, 1998), (Koschke, 2006), (Evans, 2007)
- Program Dependence Graph
  - (Komondoor, 2001), (Krinke, 2001)
- Metrics
  - (Mayrand, 1996), (Kontogiannis, 1997)

Background: Clone Analysis

- The detection stage can report a lot of clones
- What to do with the clones
  - Keep them as-is
  - Refactor
- Clone analysis in the Grammarware space
  - Metrics based on variable properties and distance (Higo, 2004)
  - Relationships in the class hierarchy (Golomingi, 2001)
  - Method-level clone grouping (Balazinska, 2000)

Related Work: Clones as Models

- Clone Region Descriptors
  - Representation of clones for future monitoring and modification (Duala-Ekoko, 2007)
- Clone-Pair Model
  - Relationship of each clone pair in the group (Giesecke, 2006)
- Regional Group of Clones
  - Based on software entity locations used for determining structural relationships (Kapser, 2006)

Goal

- Representation and analysis of clones using Model-Driven Engineering (MDE)
  - Representation of clones as models via a Domain-Specific Language (DSL)
  - Analysis of these models through model transformations

Types of Clones

Original code

```
int main() {
   int x = 1;
   int y = x + 5;
   return y;
}
```

```
int func1() {
   int x = 1;
   int y = x + 5;
   return y;
}
```

Exact match

```
int func2() {
   int p = 1;
   int q = p + 5;
   return q;
}
```

Exact match with differing variable names

```
int func3() {
   int s = 1;
   int t = s + 5;
   s++;
   return t;
}
```

Near exact match

Bellon, Koschke, Antoniol, Krinke, and Merlo. Comparison and Evaluation of Clone Detection Tools, *Transactions on Software Engineering* (2007)

Types of Clones

Original code

```
int main() {
   int x = 1;
   int y = x + 5;
   return y;
}
```

```
int func1() {
   int x = 1;
   int y = x + 5;
   return y;
}
```

Exact match

```
int func2() {
   int p = 1;
   int q = p + 5;
   return q;
}
```

Exact match with differing variable names

```
int func3() {
   int s = 1;
   int t = s + 5;
   s++;
   return t;
}
```

Near exact match

Bellon, Koschke, Antoniol, Krinke, and Merlo. Comparison and Evaluation of Clone Detection Tools, *Transactions on Software Engineering* (2007)

Types of Clones

Original code

```
int main() {
   int x = 1;
   int y = x + 5;
   return y;
}
```

```
int func1() {
   int x = 1;
   int y = x + 5;
   return y;
}
```

Exact match

```
int func2() {
   int p = 1;
   int q = p + 5;
   return q;
}
```

Exact match with differing variable names

```
int func3() {
   int s = 1;
   int t = s + 5;
   s++;
   return t;
}
```

Near exact match

Bellon, Koschke, Antoniol, Krinke, and Merlo. Comparison and Evaluation of Clone Detection Tools, *Transactions on Software Engineering* (2007)

Types of Clones

Original code

```
int main() {
   int x = 1;
   int y = x + 5;
   return y;
}
```

```
int func1() {
   int x = 1;
   int y = x + 5;
   return y;
}
```

Exact match

```
int func2() {
   int p = 1;
   int q = p + 5;
   return q;
}
```

Exact match with differing variable names

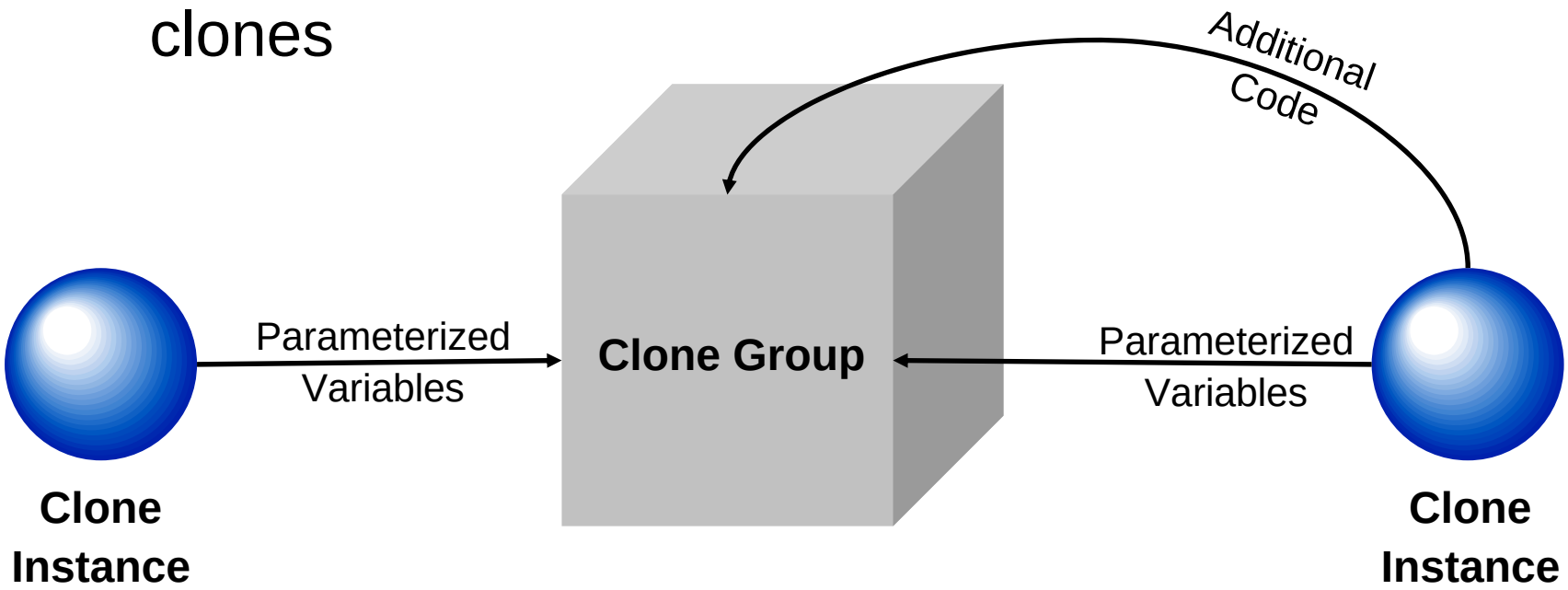
```
int func3() {
   int s = 1;
   int t = s + 5;
   s++;
   return t;
}
```

Near exact match

Bellon, Koschke, Antoniol, Krinke, and Merlo. Comparison and Evaluation of Clone Detection Tools, *Transactions on Software Engineering* (2007)

Representing Clones

- Clone group: a set of clones representing the same duplication of code
  - A clone group contains the commonalities of the clones



First DSL: Clones

```
   -- clone 1
1: int g;
2: int f = g + 3;
3: i = i + 1;
4: c = f + m;
```

```
   -- clone 2
1: int q;
2: int p = q + 3;
3: c = p + m;
```

```
   -- clone instances
1: instance r = cg(f, g) {
2:   t {
3:     i = i + 1;
4:   }
5: };
6:
7: instance s = cg(p, q);
```

```
   -- clone group
1: clone cg($a, $b) {
2:   int $b;
3:   int $a = $b + 3;
4:   {{ t }}
5:   c = $a + m;
6: }
```

First DSL: Clones

```
   -- clone 1
1: int g;
2: int f = g + 3;
3: i = i + 1;
4: c = f + m;
```

```
   -- clone 2
1: int q;
2: int p = q + 3;
3: c = p + m;
```

```
   -- clone instances
1: instance r = cg(f, g) {
2:   t {
3:     i = i + 1;
4:   }
5: };
6:
7: instance s = cg(p, q);
```

```
   -- clone group
1: clone cg($a, $b) {
2:   int $b;
3:   int $a = $b + 3;
4:   {{ t }}
5:   c = $a + m;
6: }
```

First DSL: Clones

```
   -- clone 1
1: int g;
2: int f = g + 3;
3: i = i + 1;
4: c = f + m;
```

```
   -- clone 2
1: int q;
2: int p = q + 3;
3: c = p + m;
```

```
   -- clone instances
1: instance r = cg(f, g) {
2:   t {
3:     i = i + 1;
4:   }
5: };
6:
7: instance s = cg(p, q);
```

```
   -- clone group
1: clone cg($a, $b) {
2:   int $b;
3:   int $a = $b + 3;
4:   {{ t }}
5:   c = $a + m;
6: }
```

First DSL: Clones

```
   -- clone 1
1: int g;
2: int f = g + 3;
3: i = i + 1;
4: c = f + m;
```

```
   -- clone 2
1: int q;
2: int p = q + 3;
3: c = p + m;
```

```
   -- clone instances
1: instance r = cg(f, g) {
2:   t {
3:     i = i + 1;
4:   }
5: };
6:
7: instance s = cg(p, q);
```

```
   -- clone group
1: clone cg($a, $b) {
2:   int $b;
3:   int $a = $b + 3;
4:   {{ t }}
5:   c = $a + m;
6: }
```

First DSL: Clones

```
   -- clone 1
1: int g;
2: int f = g + 3;
3: i = i + 1;
4: c = f + m;
```

```
   -- clone 2
1: int q;
2: int p = q + 3;
3: c = p + m;
```

```
   -- clone instances
1: instance r = cg(f, g) {
2:   t {
3:     i = i + 1;
4:   }
5: };
6:
7: instance s = cg(p, q);
```

```
   -- clone group
1: clone cg($a, $b) {
2:   int $b;
3:   int $a = $b + 3;
4:   {{ t }}
5:   c = $a + m;
6: }
```

Second DSL: Commands

- Input:

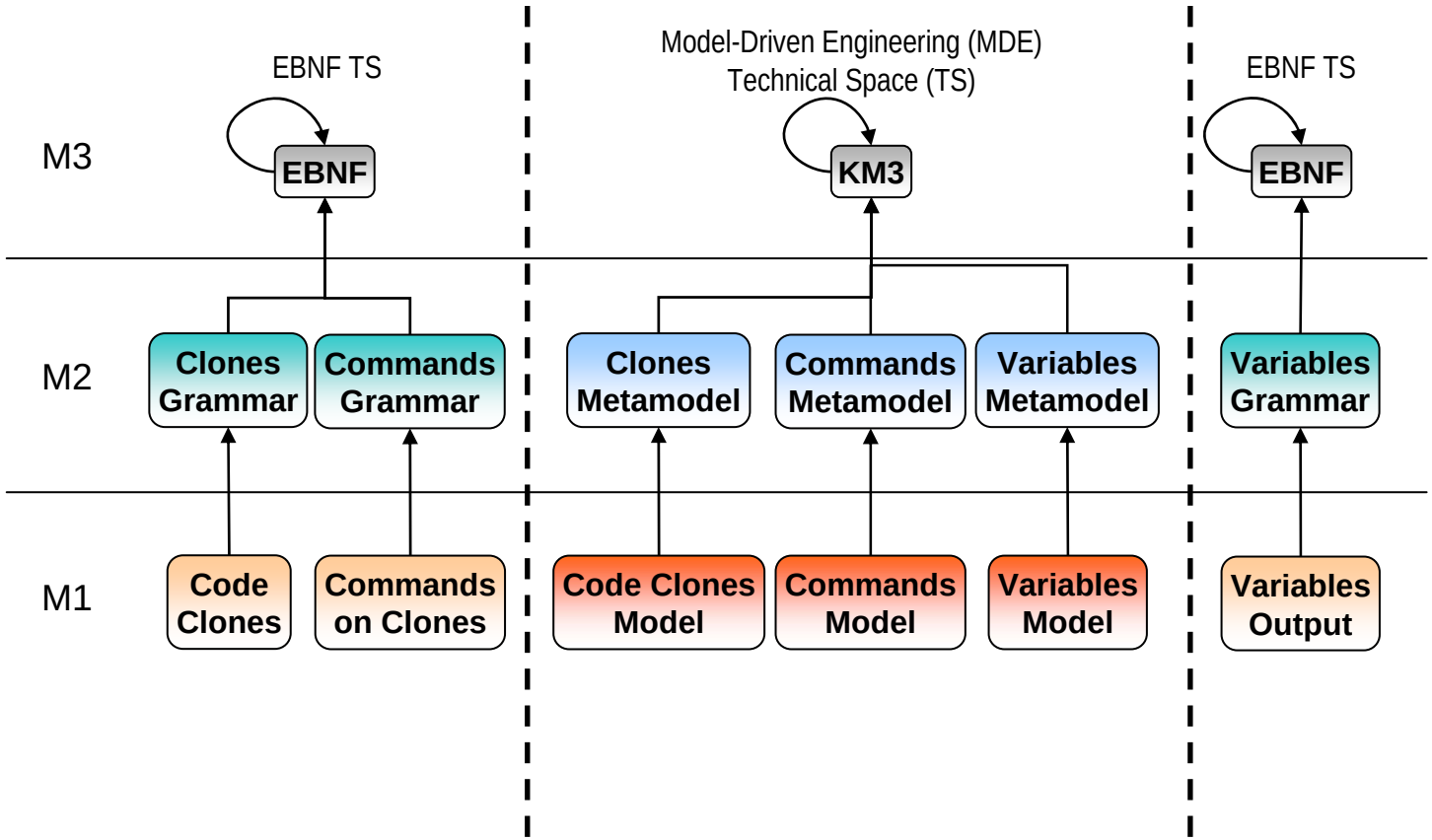
```
variables cg;
```

- Output:

```
1: Variable information for clone group cg
2: Declared variables:
3:   b
4:   a
5: Outside assigned variables:
6:   c
7:   i (in instance r)
8: Outside non-assigned variables:
9:   m
```

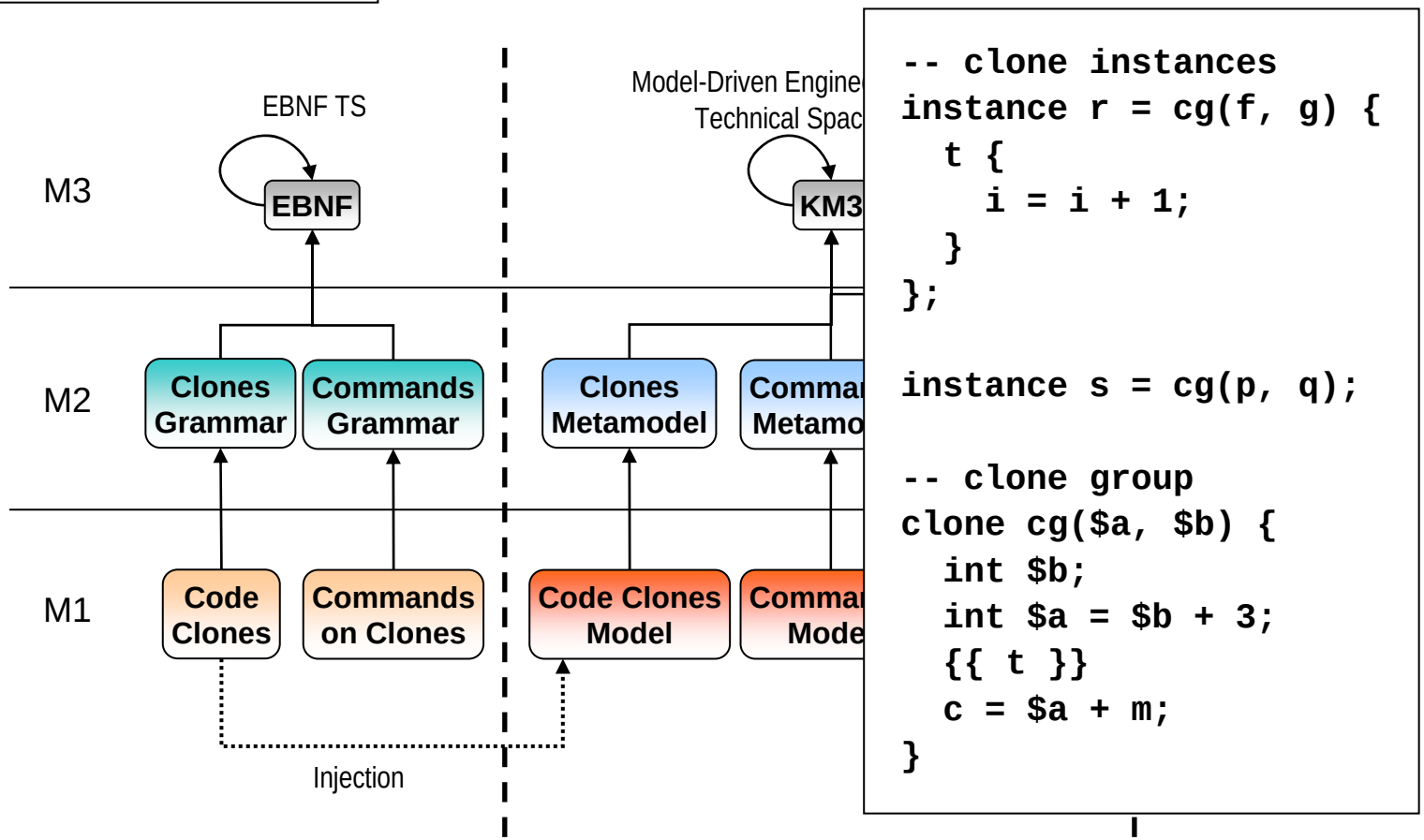
Model Transformation Process

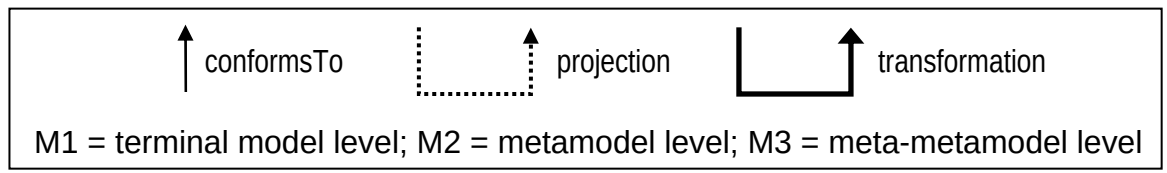
`variables` command



Model Transformation Process

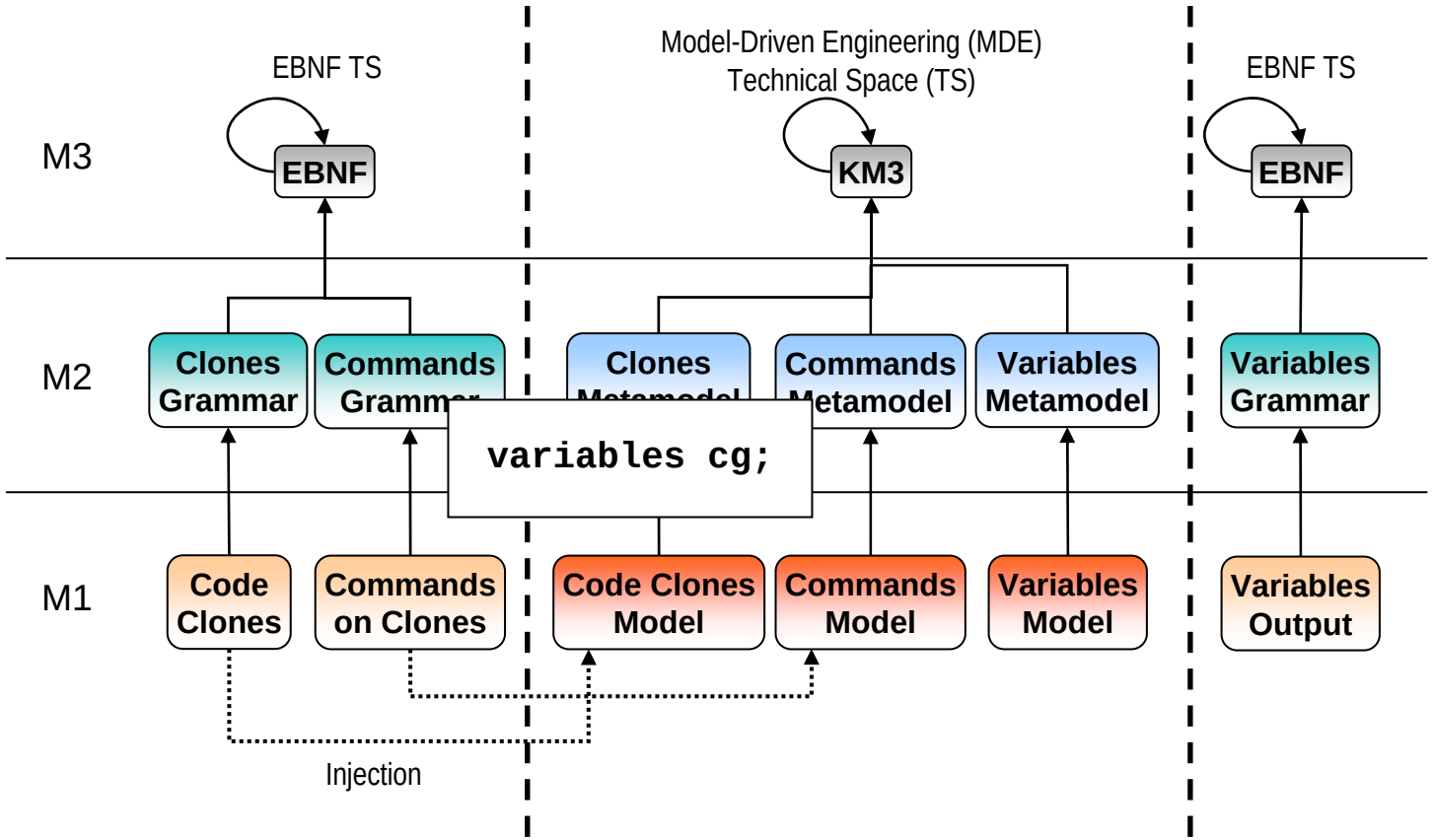
`variables` command

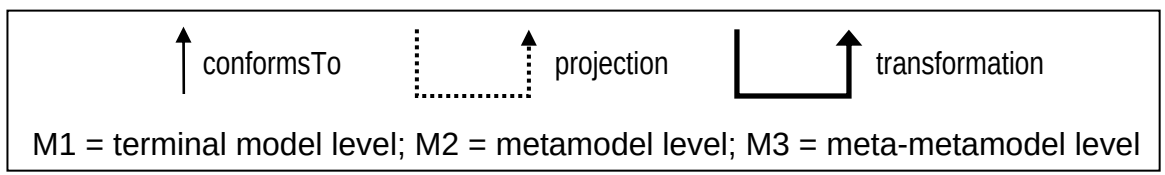




Model Transformation Process

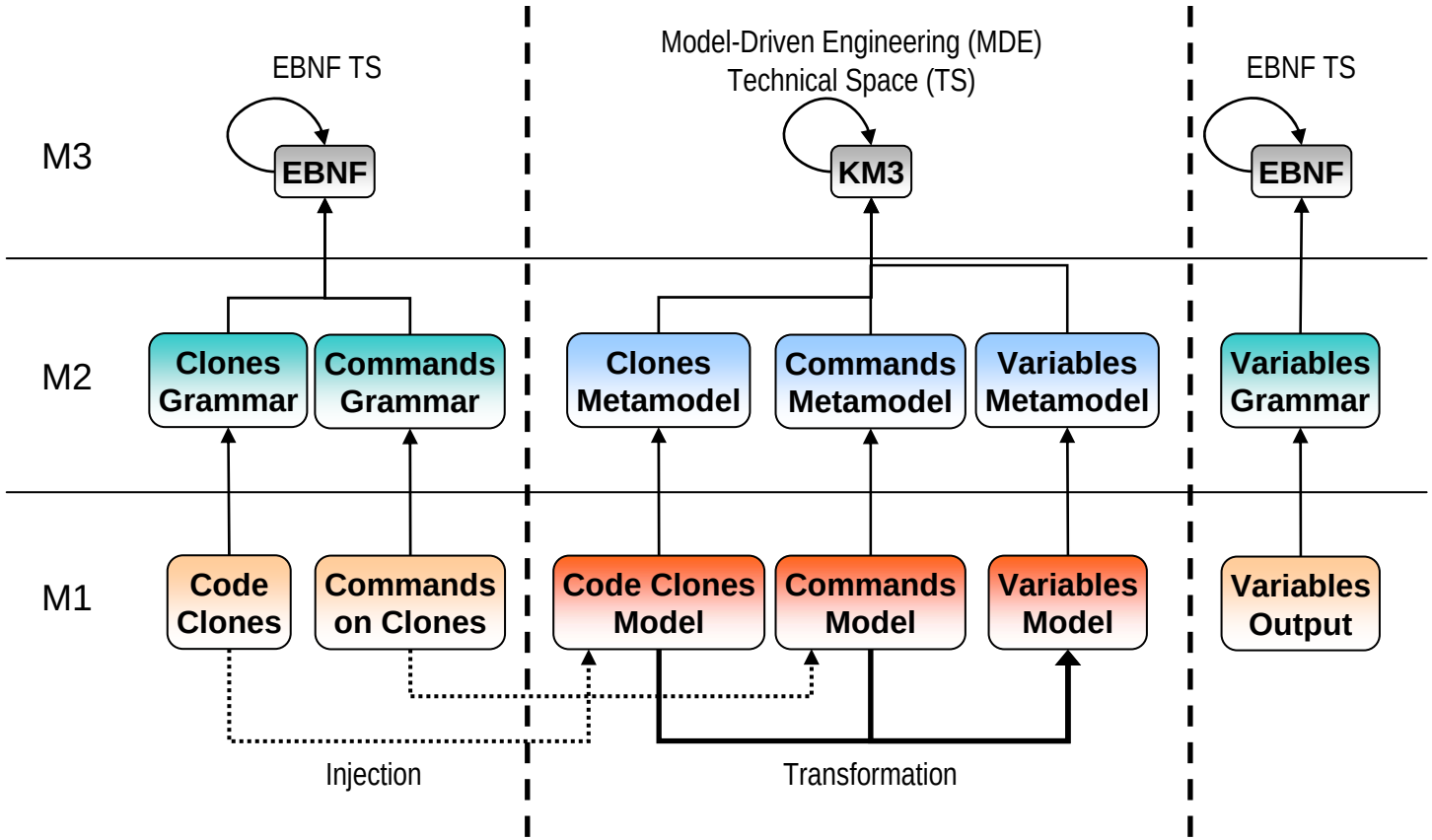
`variables` command

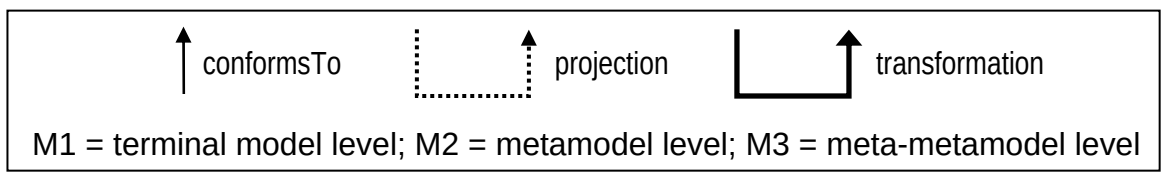




Model Transformation Process

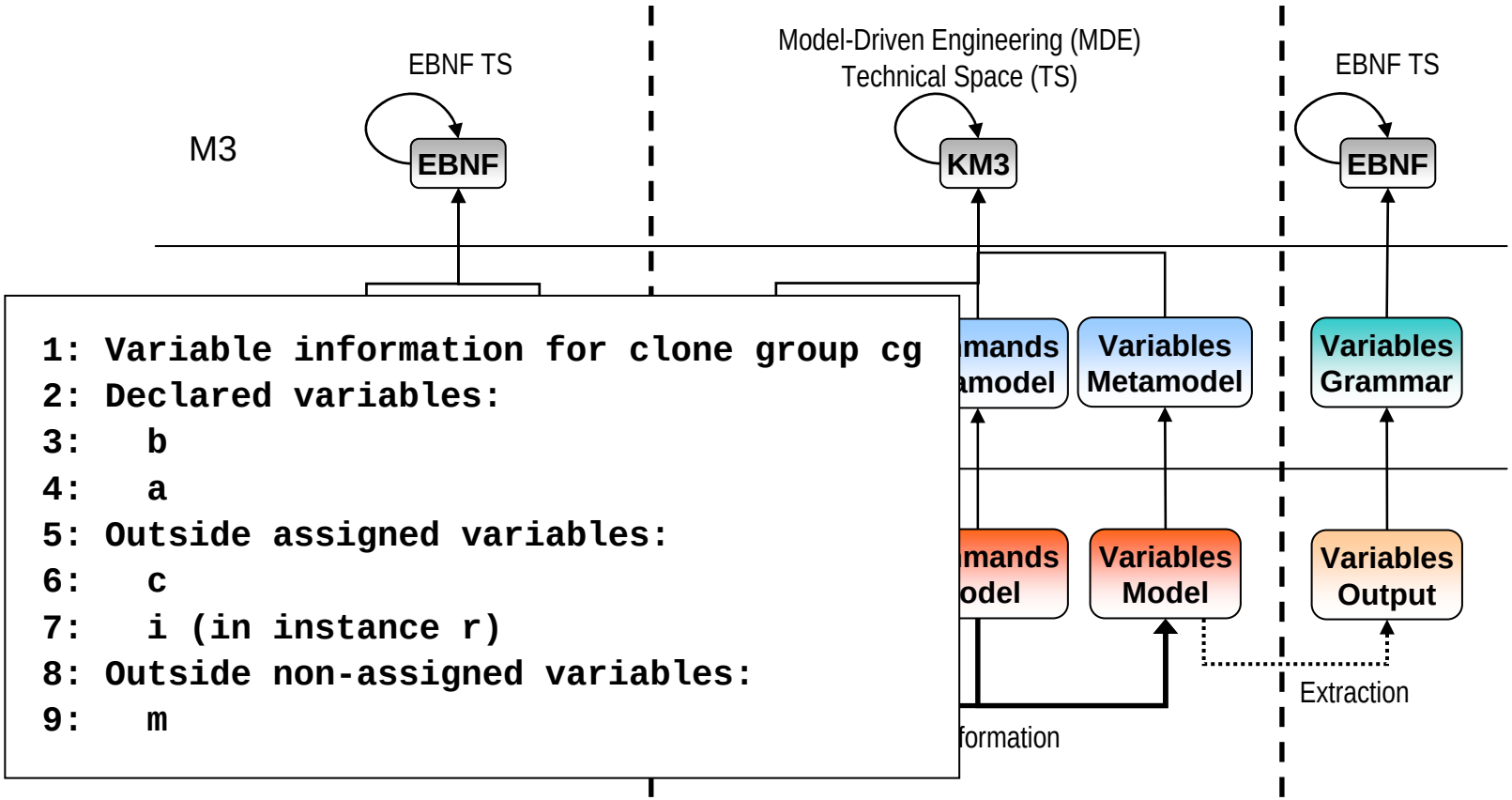
`variables` command



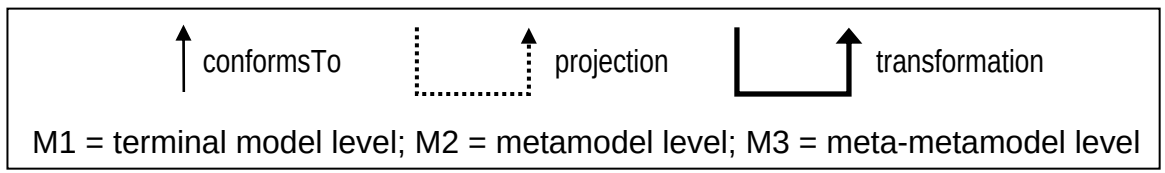


Model Transformation Process

`variables` command

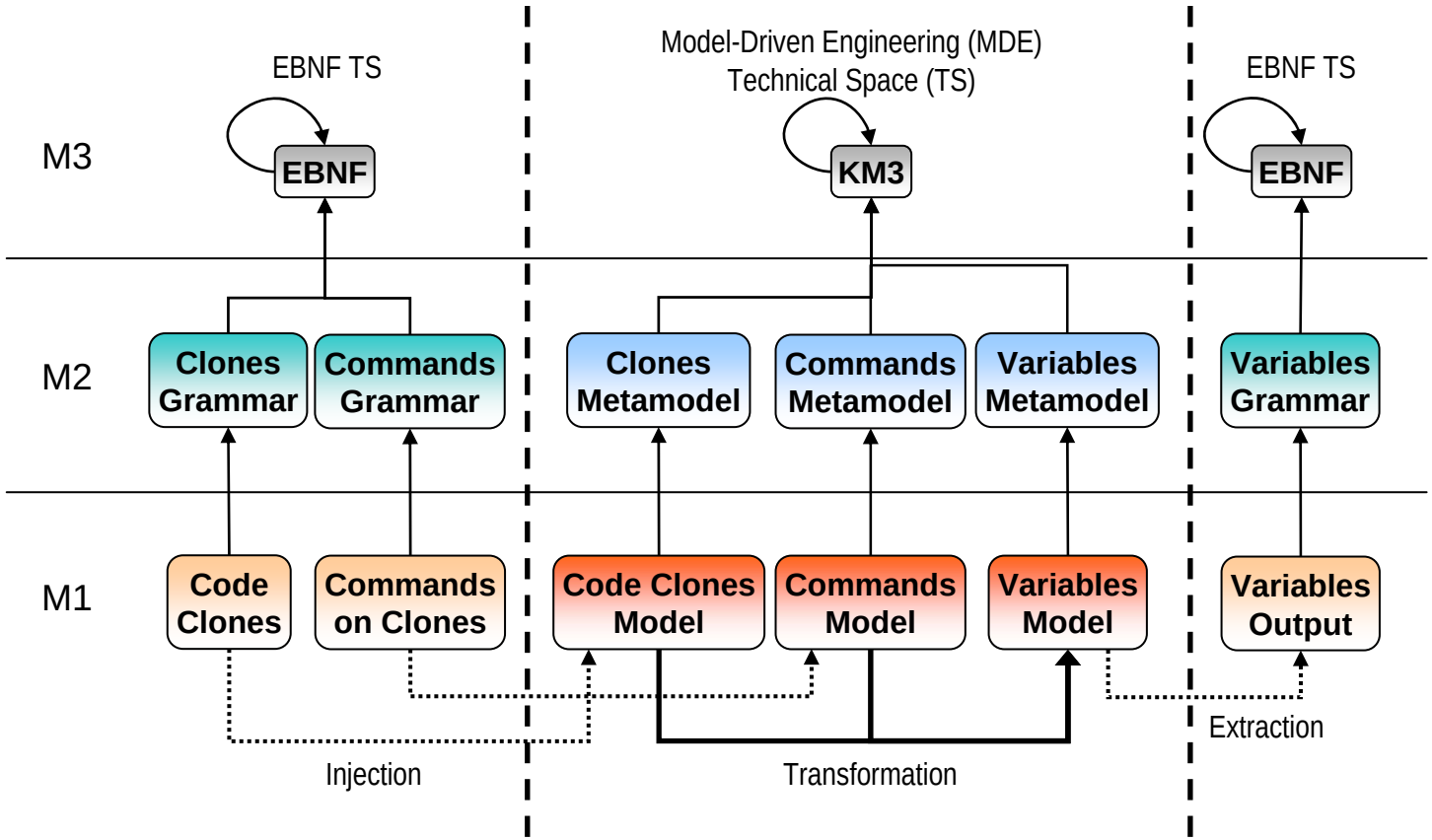


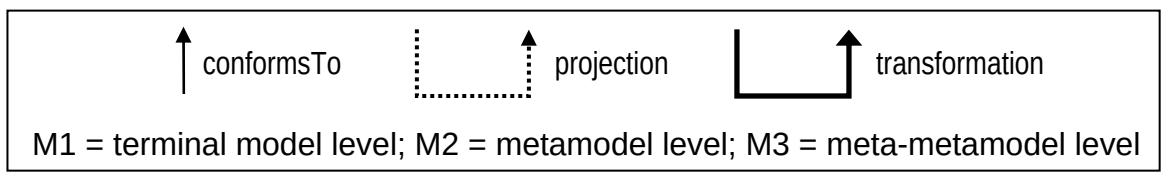

```
1: Variable information for clone group cg
2: Declared variables:
3:   b
4:   a
5: Outside assigned variables:
6:   c
7:   i (in instance r)
8: Outside non-assigned variables:
9:   m
```



Model Transformation Process

`variables` command





AMMA Platform (ATLAS Model Management Architecture)

- Platform for defining and transforming models through the following DSL's:
  - KM3: Abstract syntax
  - TCS: Concrete syntax
  - ATL: Transformations

Related Tutorial at MoDELS 2007:
"Putting MDA to Work on Eclipse with the AMMA Tool Suite"
Tuesday afternoon (October 2)

Abstract Syntax in KM3 (snippet)

```
 1:  -- Root
 2:  class Root extends LocatedElement {
 3:    reference cloneGroup[*] ordered container : CloneGroup;
 4:    reference cloneInstance[*] ordered container : CloneInstance;
 5:  }
 6:
 7:  -- Clone Group
 8:  class CloneGroup extends LocatedElement {
 9:    attribute cloneName : String;
10:    reference parameters[*] ordered container : Variable;
11:    reference statements[*] ordered container : Statement;
12:  }
13:
14:  -- Clone Instance
15:  class CloneInstance extends LocatedElement {
16:    attribute instanceName : String;
17:    reference cloneName : CloneGroup;
18:    reference arguments[*] ordered container : Variable;
19:    reference boxes[*] ordered container : Box;
20:  }
```

Abstract Syntax in KM3 (snippet)

```
 1:  -- Root
 2:  class Root extends LocatedElement {
 3:    reference cloneGroup[*] ordered container : CloneGroup;
 4:    reference cloneInstance[*] ordered container : CloneInstance;
 5:  }
 6:
 7:  -- Clone Group
 8:  class CloneGroup extends LocatedElement {
 9:    attribute cloneName : String;
10:    reference parameters[*] ordered container : Variable;
11:    reference statements[*] ordered container : Statement;
12:  }
13:
14:  -- Clone Instance
15:  class CloneInstance extends LocatedE
16:    attribute instanceName : String;
17:    reference cloneName : CloneGroup;
18:    reference arguments[*] ordered con
19:    reference boxes[*] ordered contain
20:  }
```

```
-- clone group
clone cg($a, $b) {
  int $b;
  int $a = $b + 3;
  {{ t }}
  c = $a + m;
}
```

Abstract Syntax in KM3 (snippet)

```
 1:  -- Root
 2:  class Root extends LocatedElement {
 3:    reference cloneGroup[*] ordered container : CloneGroup;
 4:    reference cloneInstance[*] order                    tance;
 5:  }
 6:
 7:  -- Clone Group
 8:  class CloneGroup extends LocatedEl
 9:    attribute cloneName : String;
10:    reference parameters[*] ordered
11:    reference statements[*] ordered
12:  }
13:
14:  -- Clone Instance
15:  class CloneInstance extends LocatedElement {
16:    attribute instanceName : String;
17:    reference cloneName : CloneGroup;
18:    reference arguments[*] ordered container : Variable;
19:    reference boxes[*] ordered container : Box;
20:  }
```

```
-- clone instances
instance r = cg(f, g) {
  t {
    i = i + 1;
  }
};

instance s = cg(p, q);
```

Concrete Syntax in TCS (snippet)

```
 1:  -- Root
 2:  template Root main
 3:    :  cloneGroup cloneInstance
 4:    ;
 5:
 6:  -- Clone Group
 7:  template CloneGroup context addToContext
 8:    :  "clone" cloneName "(" parameters{separator = ","} ")"
 9:       "{" statements "}"
10:    ;
11:
12:  -- Clone Instance
13:  template CloneInstance context addToContext
14:    :  "instance" instanceName "=" cloneName{refersTo = cloneName}
15:       "(" arguments{separator = ","} ")"
16:       (isDefined (boxes) ? "{" boxes{separator = ","} "}" ) ";"
17:    ;
```

Tranformation in ATL (snippet)

```
 1:  lazy rule DeclaredVar {
 2:    from s : Clones!CloneGroup
 3:    to t   : Variables!DeclaredVar (
 4:       variables <- Sequence {
 5:          s.statements->collect(e |
 6:            if e.oclIsKindOf(Clones!DeclarationStat) then
 7:              e.variable.varName
 8:            else
 9:              Sequence{}
10:            endif
11:            ) ,
12:            thisModule.processBox1(s.cloneName)
13:       }
14:    )
15:  }
```

```
-- clone group
clone cg($a, $b) {
  int $b;
  int $a = $b + 3;
  {{ t }}
  c = $a + m;
}
```

Tranformation in ATL (snippet)

```
 1:  helper def: processBox1(t: String): Sequence(OclAny) =
 2:    Clones!CloneInstance.allInstancesFrom('IN1')
 3:      ->select(e | e.cloneName.cloneName = t)
 4:      ->iterate(f;
 5:        test : Sequence(OclAny) = Sequence{} | test->including(
 6:          if f.boxes->size() = 0 then
 7:            Sequence{}
 8:          else
 9:            f.boxes->collect(g | g.statements)->flatten()
10:              ->collect(h |
11:                if h.oclIsKindOf(Clones!DeclarationStat) then
12:                  h.variable.varName + ' (in ' + f.instanceName + ')'
13:                else
14:                  Sequence{}
15:                endif
16:            )
17:          endif
18:        )
19:     );
```

```
-- clone instances
instance r = cg(f, g) {
  t {
    i = i + 1;
  }
};

instance s = cg(p, q);
```

Summary

Initial effort of representation and analysis of clones using MDE:

- Representation of clones (as models)
  - Commonalities stored in clone groups
  - Uniqueness stored in clone instances
- Analysis of clones (via model transformations)
  - Transformations with both declarative and imperative constructs

Future Work

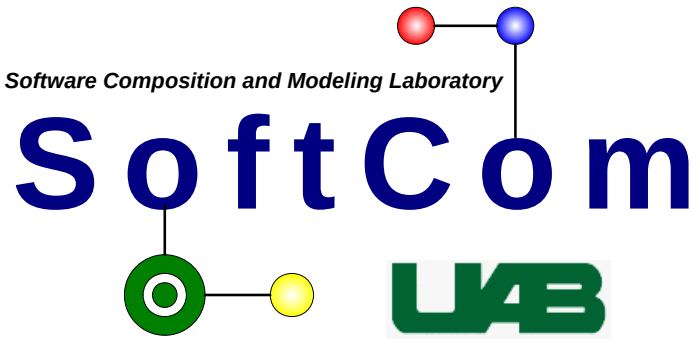
- Reunited
  - Instead of a separate metamodel for clone representation, consider “extending” metamodel of source program
- Comparison
  - More detailed comparisons with existing approaches

Thank you. Questions?

- CoCloRep Project: http://www.cis.uab.edu/tairasr/coclorep
- Clone Detection Literature: http://www.cis.uab.edu/tairasr/clones/literature
- SoftCom Laboratory: http://www.cis.uab.edu/softcom

Robert Tairas

tairasr@cis.uab.edu



Department of Computer and Information Sciences
University of Alabama at Birmingham

This project is supported by
NSF grant CPA-0702764 and the OpenEmbeDD project