Model Transformation with Operational QVT

QVT Operational - M2M component

http://www.eclipse.org/m2m

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Agenda

- Overview of QVT Operational language
- M2M/QVTO + tooling support
- Examples
    - Simple illustrative Ecore2Emof
    - MDD use-case within GMF project
- Q&A

Operational QVT

- Final Adopted Specification - ptc/07-07-07
- Why operational?
- Designed for transformations that have to build target models of a complex structure
- In cases when there is no direct correspondence between individual elements of the source and target models -> might be difficult to describe declaratively
- QVTo – imperative (procedural) language specifying explicit steps to execute in order to produce the result

Operational Transformation

- Defines the process of converting {1..*} source models into {1..*} target models.
- The most typical scenario - Ma conforming to metamodel MMa converted into a model Mb conforming to metamodel MMb.
- If Ma=Mb -> *in-place* transformation
- The metamodels involved in the transformation are manifested in transformation signature.

transformation MMaToMMb(**in** Ma : MMa, **out** Mb: MMb);

- Set of typed model parameters indicate the referred metamodels and provides a mechanism for inspecting actual model instances in runtime.
  - **in** | **out** | **inout** direction kind -> restrictions to object creation, changeability

Model type declaration

- Model type is the type of transformation model parameters
- **Implicit** - no model type is declared explicitly; the metamodels can be resolved by name -> the effect of implicit model type declaration, taking the name of referred metamodel.
- **Explicit** - a concrete syntax construct placed before transf. signature

modeltype MMa **uses** “http://qvtexample/mm/MMa”;

- The used metamodels are referred by ***uri*** identifying the metamodel package or by package name
- Model type identifier can be part of qualified type names to resolve ambiguities -> MMa**::**A

Model type declaration advanced

- Metamodel conformance kind can be specified
  - effective - (default) structural match based; indicates a declaration time metamodel, the *actual* metamodel involved at runtime, typically different versions of logically the same metamodel with compatible changes -> flexibility, high applicability
  - strict - model objects must be instance of the exact classes from the referred metamodels, required for XMI serialization

- Restricting conditions on metamodels accepted by transformations

modeltype MMa **uses** “http://qvtexample/mm/MMa”
where { **self**.objectsfOfType(*A*)->notEmpty() };

- Allows for validation check on input models without executing the transformation, using **self** variable of model type instance (a model)

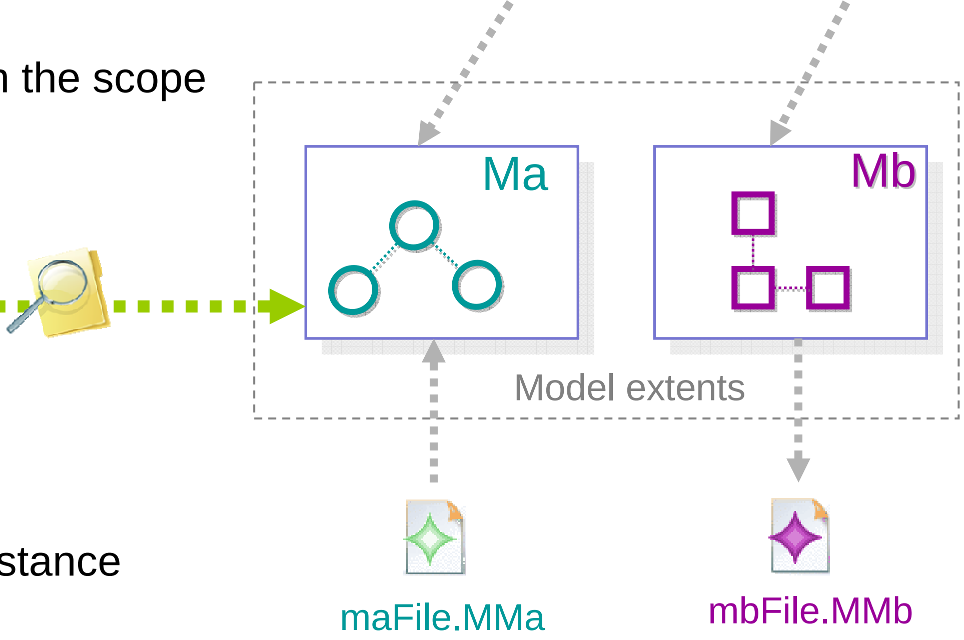
Model parameters

- A MOF extent is associated with every model parameter, provides model elements container
- Model elements queried or created in the scope of parameter associated extent

```
-- all A instances
Ma.objects()[A];
-- all out B instances
Mb.objects()[B];
```

- Transformation is a class; a single instance instantiated by implicit constructor
  - the contents of **in | inout** parameters extents is initialized
  - **out** parameters created with empty model extent
  - model parameters mapped to attribute slots, accessible within transformation, **this** variable refers to transformation

```
transformation MMaToMMb
    (in Ma : MMa, out Mb: MMb);
```

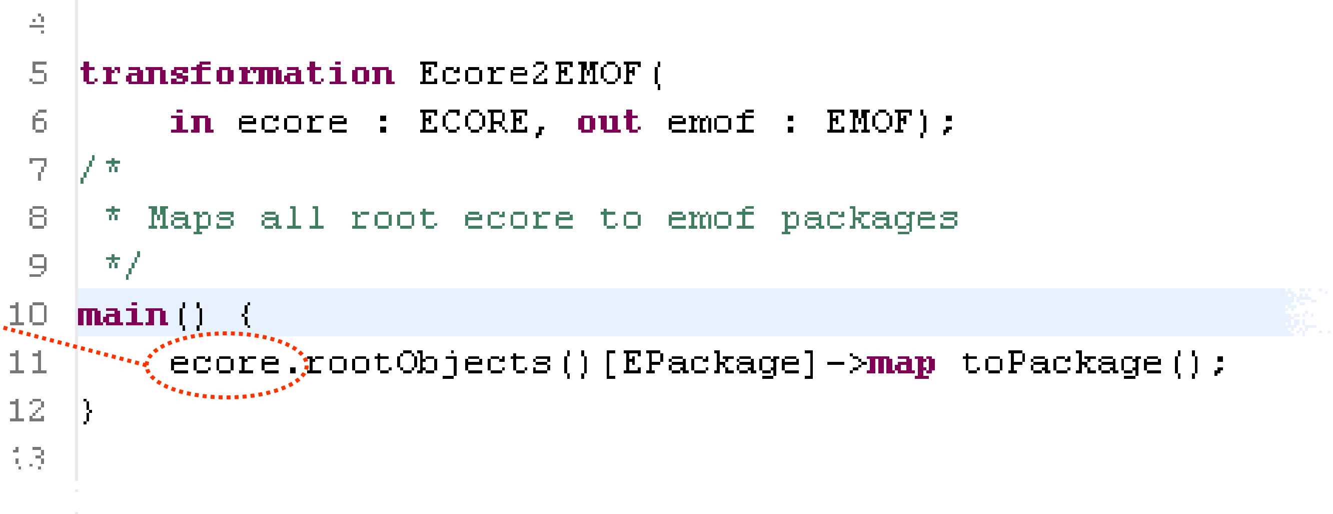


Transformation entry point

- **main()** – signature-less imperative operation, sequentially executes list of expressions - *body*

- First and last transformation operation executed
- Called automatically after transformation implicit instantiation
- Single **main** operation per transformation
- abstract transformations, designed for reuse and not direct execution – no entry operation defined

Typically, selects elements within **in** model parameter extents -> source objects to mapping calls



```
transformation Ecore2EMOF(
    in ecore : ECORE, out emof : EMOF);
/*
 * Maps all root ecore to emof packages
 */
main() {
    ecore.rootObjects()[EPackage]->map toPackage();
}
```

Mapping operation

- Maps {1..*} source model elements into {1..*} target elements
- Source and target types indicated by operation signature

QVT Operational

Relations

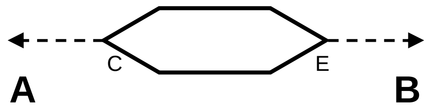
```
--Mapping operation
mapping A::AtoB() : B;
```

source type

target type

refines

implicit relation



```
--Mapping operation call
a.map AtoB();
--target resolvable now
assert (a.resolve()->notEmpty());
```

realizes

- creates trace instance
- relation holds after execution

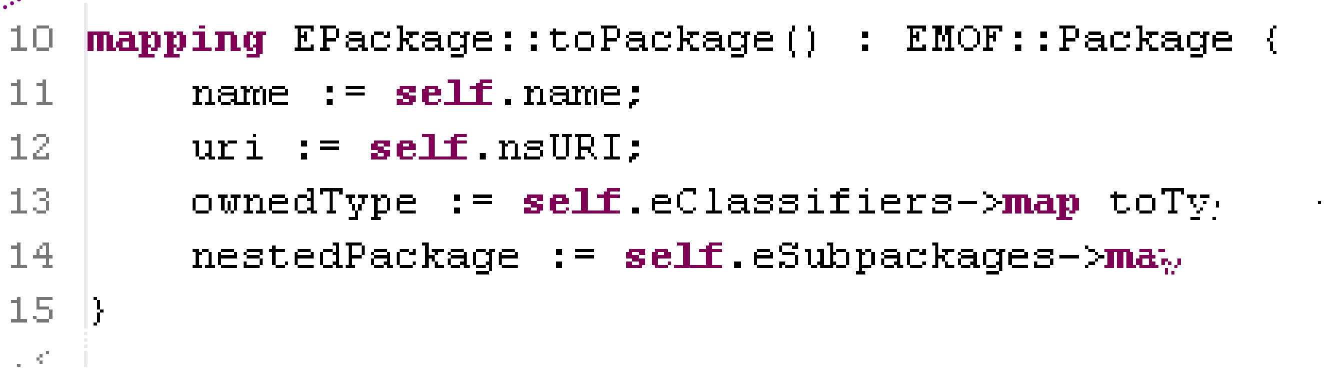
Mapping operation definition

<qualifiers>? mapping <param-direction-kind>?
(<contexttype>::)?<identifier>(<parameters>?) (: <result-parameters>)?
<extensions>? <when>? <where>?
{ <mapping-body> }

Is that so complex to write a mapping?

mapping (<contexttype>::)?<identifier>() : <result-parameters>) ?
{ <mapping-body> }

The most frequent case -> let's start with that

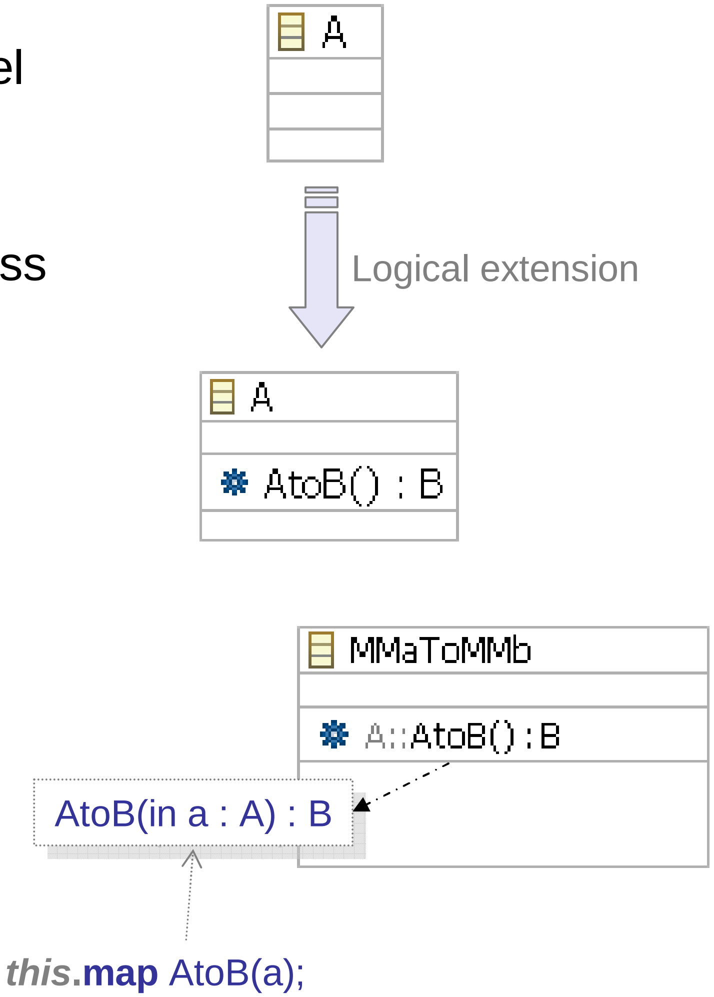


```
mapping EPackage::toPackage() : EMOF::Package {
    name := self.name;
    uri := self.nsURI;
    ownedType := self.eClassifiers->map toTy
    nestedPackage := self.eSubpackages->ma
}
```

Contextual mapping operation

- **logically** extends the context type -> model element as source of mapping calls
- physically owned by the transformation class

```
transformation MMaToMMb(
           in Ma : MMa, out Mb : MMb);
main() {
  var a := Ma.rootObjects![A];
  a.map AtoB();
}

mapping A::AtoB() : B {
}
```



this.**map** AtoB(a);

Contextual mapping operation environment

mapping (<contexttype>::)?
<identifier>(<parameters>?) : <result-parameters>)?

Mapping parameter – indicates direction kind

- ***in*** - object passed for read-only access, the default direction
- ***inout*** - passed object for update, retains its value
- ***out*** - receives new value (not necessarily newly created object)

```
-- Contextual
mapping A::AtoB() : B {
}
```

Operation environment

self : A -> **in** contextual parameter - implicit
result : B -> **out** parameter - implicit

```
-- Non-contextual
mapping AtoB(in a : A) : B {
}
```

a : A -> **in** parameter - explicit
result : B -> **out** parameter - implicit

Mapping operation with when clause

mapping A::AtoB() : B **when** { **self**.isValid() }
{ }

- boolean expression
- access to mapping parameters

Execution semantics dependent on invocation mode
standard | **strict**

when { *false* }

- **guard** – selects model elements for mapping
  a.**map** AtoB(); *-- std call semantics*
- **pre-condition** – must be always satisfied
  a.**xmap** AtoB(); *-- strict call semantics*

std → Body not executed, returns ***null***

strict → Body not executed, exception is thrown

Mapping operation body

- variable assignments; keeps intermediate results
- uses query, mapping and resolve calls
- explicit **out** parameter assignment

initialization

1) New instances created assigned to un-initialized **out** parameters
2) **Trace** instance created -> relation holds

instantiation

updating **inout**, **out** instances using object or assignment expressions

population

final computations before exiting, typically additional mapping invocations, logging, assert

termination

```
mapping A::AtoB() : B {

init {
   var d := self.resolveone(D);
}



propOfB := self.propOfA;
refToC := self.map AtoC();


end {
   result.refToC.map modifyC(d);
}
```

Mapping operation body – object instantiation

Implicit instantiation section - creates out parameters instances

```
result := new B();
```

```
-- no init section
mapping A::AtoB() : B {
    name := self.name;
}
```

Init section - may create out objects explicitly

```
mapping A::AtoB() : B {
  init {
    if (condition1) then {
          result := object SubTypeOfB { };
    } endif;
  }
  name := self.name;
}
```

```
if (result = null) then
  result := new B();
```

Mapping operation body – object population

Modifications of instantiated **inout** | **out** objects

```
-- implicit population section
mapping A::AtoB() : B {
   name := self.name;
}
```

expand as

```
-- explicit population section
mapping A::AtoB() : B {
   population {
        object result : B {
                name := self.name;
        }
   }
}
```

Multiple results

```
mapping A::AtoBC() : b: B, c: C {
 population {
   object b: B { name := self.name; }
   object c: C { name := self.name; }
 }
}
```

may reduce

```
mapping A::AtoBC() : b: B, c: C {
   object b: B {
       name := self.name;
   };
   object c: C {
       name := self.name;
   }
}
```

Inline instantiation

- Object expression – refers to the instantiated class, provides a body to initialize new instances
- Used for simple tasks where mappings are not desirable
- Instantiated objects not reachable by **resolve** call – no traces created
- **Create** or **update** semantics controlled by use of variable referring to created/updated objects
- Poor reusability level -> solved by **constructors**

```
-- always new instance
object A {
};

var a := null;
-- (a = null) new instance set to a
object a : A {
  name := 'Rich';
};

-- (a <> null) -> update
object a : { -- type known already
  name := a.name + ' ' + 'Gronback';
};
```

Assignment expression

- Assignment of a right side value to the target **property** or **variable** on the left side

- Assignments semantics for targets of collection type
  - ***null*** values skipped from assignment
  - duplicates eliminated when assigning to *Set, OrderedSet* target types
  - ◆ Reset semantics

```
elements := Sequence {}; -- set empty target collection
```

  - ◆ Additive semantics (collections only)

    - all left side (non-**null**) values added to the original contents

```
elements += object Element {}; -- single element added
-- adds 2 elements -> 3 elements in the target property
elements += Sequence { object Element {}, object Element {} };
```

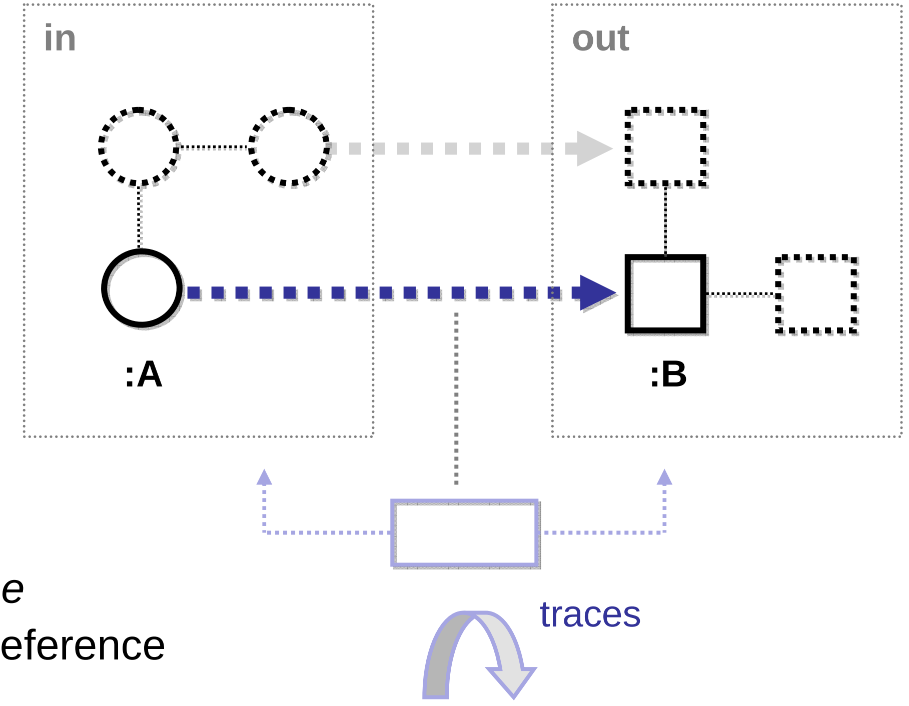
Mapping invocation semantics

```
main() {
  var a: A := object SubA {};
  a.map AtoB();
}

mapping A::AtoB() : B {
}

mapping SubA::AtoB() : B {
}
```

1. Resolve mapping operation based on the actual context instance – *virtual call.*
2. Check ***when*** clause if not satisfied -> return ***null***
3. Guard succeeded, a check for existing trace for the given sources, targets is performed.
4. If the relation holds -> result parameters fetched from traces and returned; otherwise body is executed

Resolving objects

- Supported by resolve expression family
- Based on trace inspection -> only mapping operation source, targets can be resolved



a.**resolve**(B)

Execution semantics modifiers

- **Direction** – source to target or *inverse*
- **Specific mapping** – given mapping reference
- **Multiplicity** – resolve one or many
- **Filtering condition** – only matching object
- **Time** – resolve now or at deferred time

Typical use-cases:

Updating objects resulting from executed mappings

Checking whether a mapping already executed

Realizing transformed model cross-referencing

Resolve examples

- Direction

  *a.**resolve**();* *-- source -> target*

  *b.**invresolve**();* *-- target -> source*

- Specific mapping

  a.**resolveIn**(A::AtoB, B);

- Multiplicity of result type

  a.**resolveone**(B); *-- single Object*

  a.**resolve**(B); *--Sequence(Object)*

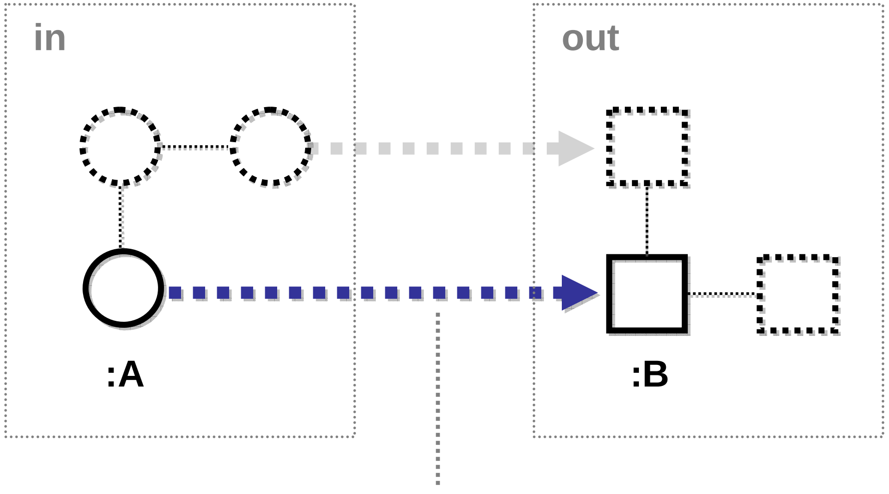
- Time

  -- resolve now

  a.**resolveone**(B);

  -- resolve at deferred time

  a.**late resolveone**(B);



mapping A::AtoB() : B

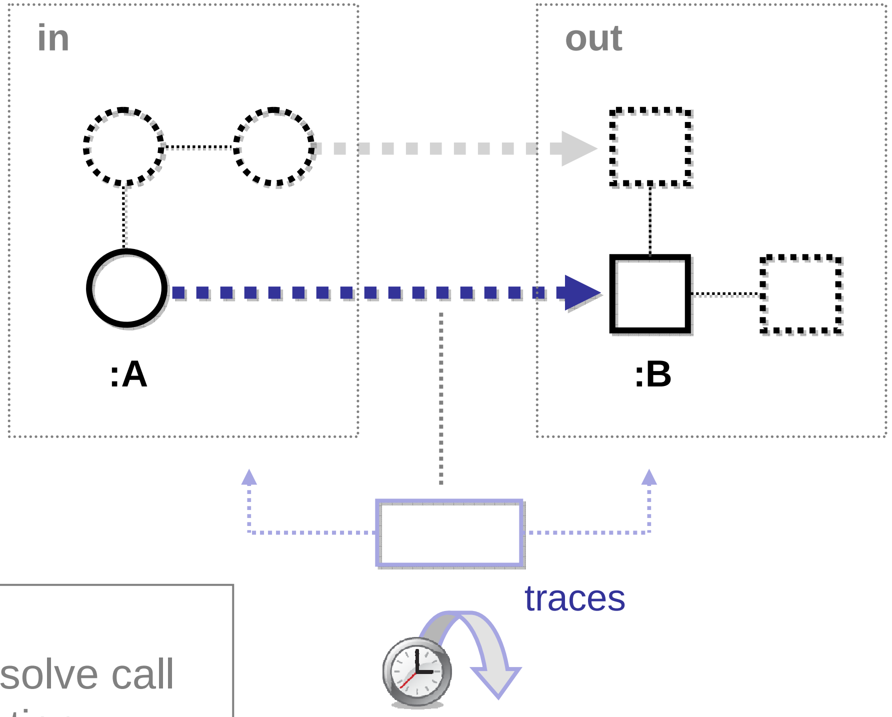
- Filtering condition & result type

  a.**resolveone**(name='Joe'); *-- Object*

  a.**resolve**(A); *-- Sequence(A)*

  a.**resolve**(a : A | a.name <> null);

Late resolve



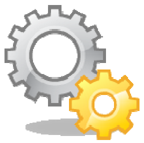
Normal execution time

object A {
  refToB := findSource().**late resolveone**(B);
}

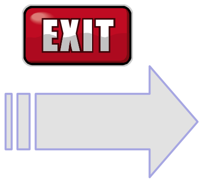
1. Assignment not executed
2. Evaluates the **source** object of late resolve call
3. Stores all data required for later execution

main() {

…



} // end of transformation



Executes deferred assignments in sequence as detected by normal execution

inout - Mapping operation

<qualifiers>? mapping **<param-direction-kind>?**
(<contexttype>::)?<identifier>(<parameters>?) (: <result-parameters>)?
<extensions>? <when>? <where>?

- **param-direction-kind**
  - direction of the contextual parameter (if available)
  - possible values (**in** | **inout**);
  - **in** - the default direction, not notated

Operation environment

```
mapping inout A::updateA() {
}
```

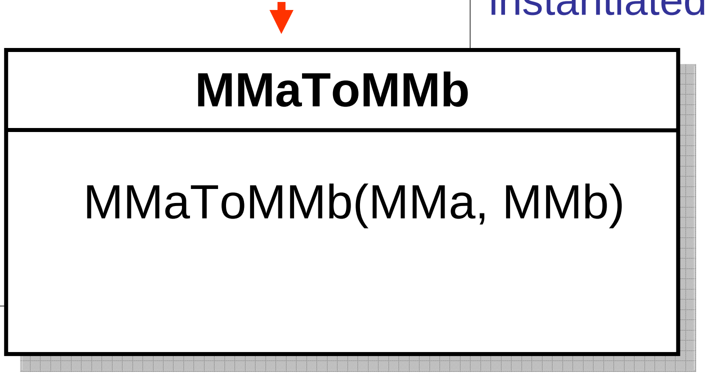
self : A -> **inout** contextual parameter - implicit

```
mapping inout A::updateA() : A {
}
```

self : A -> **inout** contextual parameter - implicit
result : A -> **out** parameter - implicit

Reuse by composition

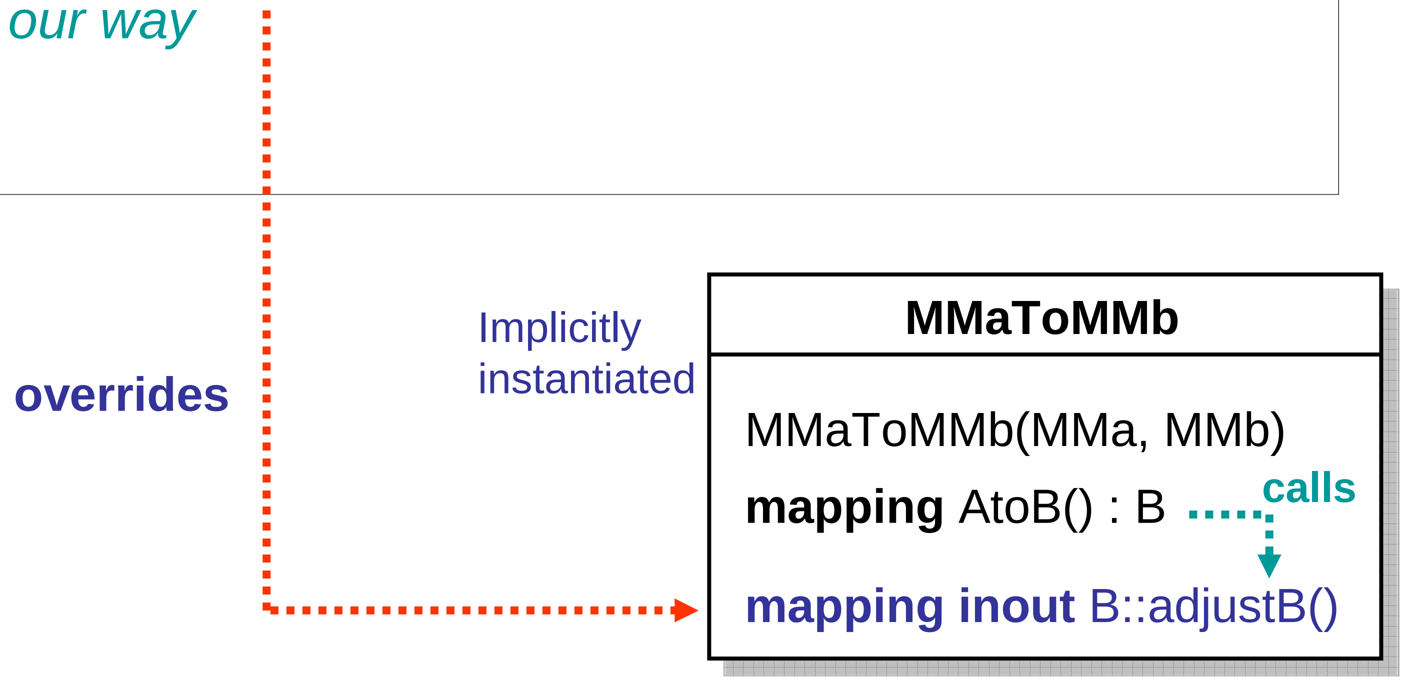
```
transformation MMaToMMbExt(
      in Ma : MMa, out Mb : MMb)
      access transformation MMaToMMb(in MMa, out MMb);

main() {
   var a2b : AtoB := new MMaToMMb(Ma, Mb);
   a2b.transform();

   Mb.objects()[B]->map processB();
}

mapping inout B::processB()  {
   …
}
```



Explicitly instantiated

Reuse by extension

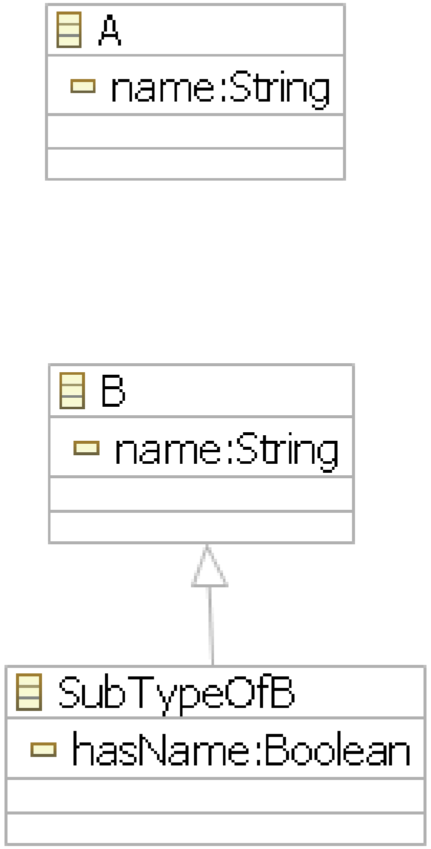
```
transformation MMaToMMbExt(in ma : MMa, out mb : MMb)
    extends transformation MMaToMMb(in MMa, out MMb);

mapping inout B::adjustB () {
  -- do it our way
}
```



Mapping level reuse facility - *inherit*

```
mapping A::AtoB() : B {
  name := self.name;
}

mapping A::AtoSubB() : SubTypeOfB
  inherits A::AtoB
{
  init {
     var nullName := self.name = null;
  }
  hasName := not nullName;
}
```

calls



Mapping level reuse facility - *merge*

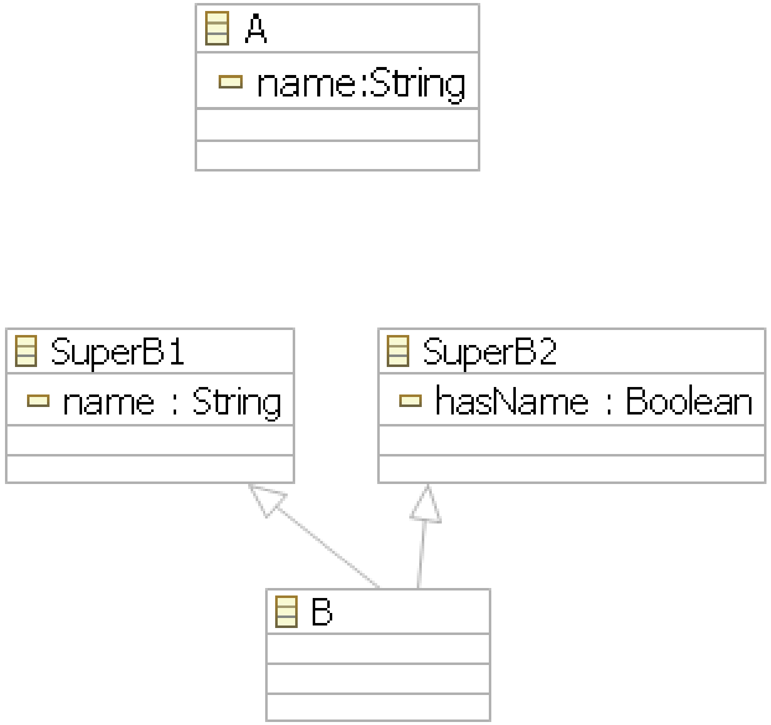
1.

```
mapping A::toSuperB1() : SuperB1 {
  name := self.name;
}
```

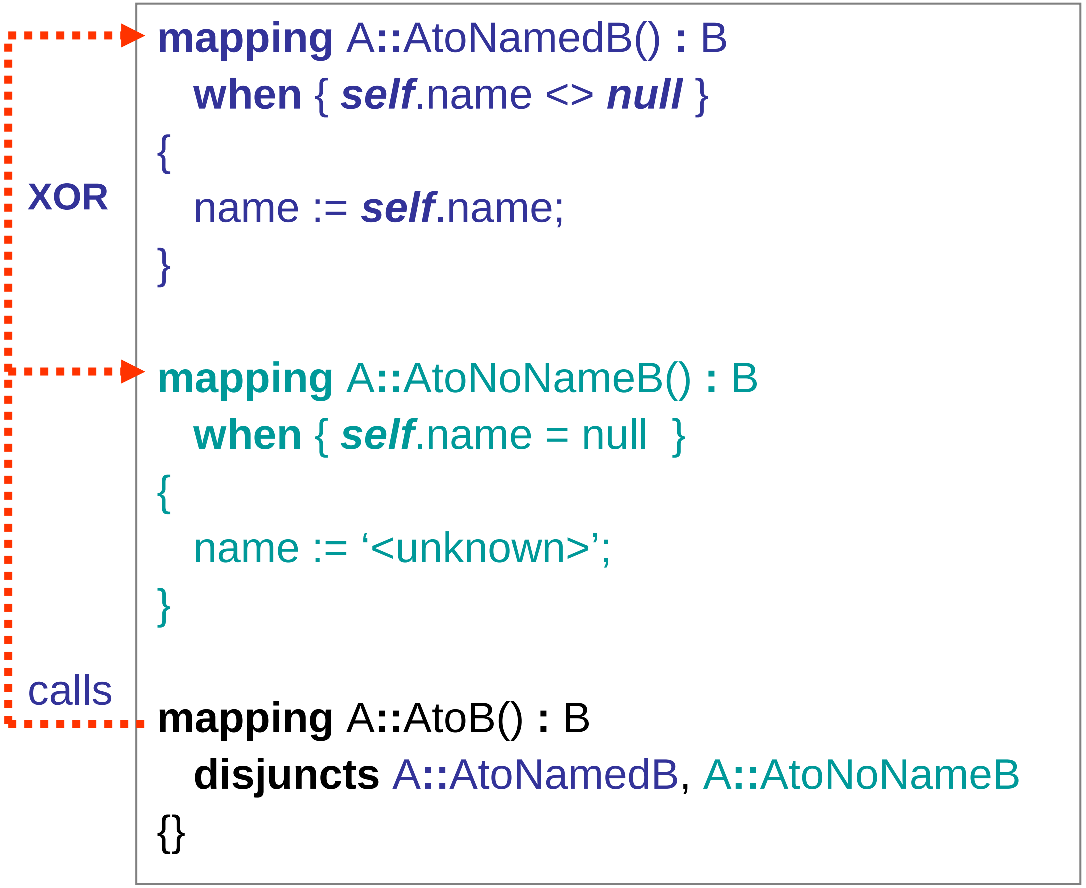
2.

```
mapping A::toSuperB2() : SuperB2 {
  hasName := self.name <> null;
}

mapping A::AtoB() : B
  merges A::toSuperB1, A::toSuperB2
{
  end {
  }
}
```

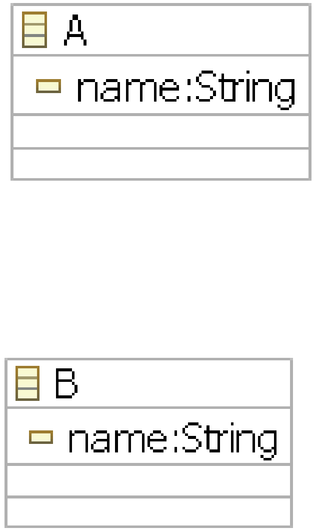
calls



Mapping level reuse facility - *disjunct*



```
mapping A::AtoNamedB() : B
   when { self.name <> null }
{
   name := self.name;
}

mapping A::AtoNoNameB() : B
   when { self.name = null  }
{
   name := ‘<unknown>’;
}

mapping A::AtoB() : B
   disjuncts A::AtoNamedB, A::AtoNoNameB
{}
```

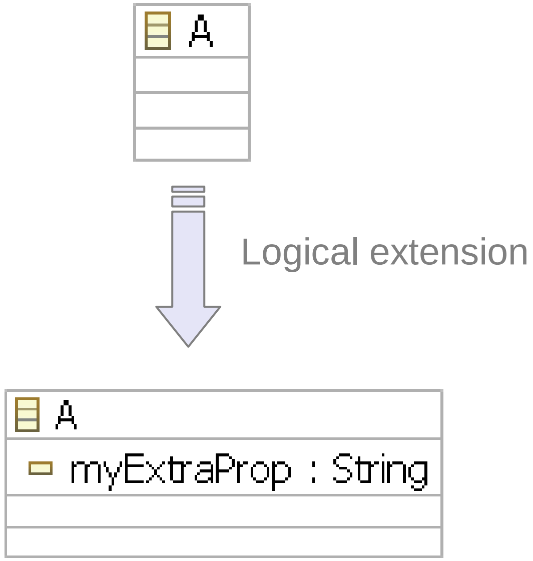


- Selects the first match by type and satisfied guard
- Returns ***null*** if no mapping can be selected

Contextual (intermediate) property

- Similar concept as contextual operation
- Owned by transformation class but logically extends the context type
- Exists only in the scope of defining module
- Manipulated as regular properties – read/ write access

```
property A::myExtraProp : String;

main() {
  object A {
     myExtraProp := 'a String';
  };
}
```



Intermediate classes

- Ordinary classes defined purely for the internal purpose of a transformation.
- Only in the scope of the defining transformation
- In case it's referenced in traces, persistence must be ensured
- Typically used for additional structural working data associated with instances of existing classes, usually from (read-only) metamodels.

intermediate class DataForA {

extraProperty : String;

}

intermediate property A::extraData : DataForA;

Instantiation in specific model extents

- In simple cases – target model extents resolved automatically
- Multiple model pameters of **inout** | **out** direction kind of the same model type can be solved by explicit instruction
- Option for explicit indication of the target extent by referring to a model parameter
- However, model elements may move between model extents due to containment reference assignments

```
transformation MMaToMMb(
    in Ma : MMa, out Mb : MMb,
    out mbExt : MMb);

main() {
    object B@mbExt {
      name := 'John';
    }
}

mapping A::AtoB() : B@Mb {
}
mapping A::AtoBExt() : B@MbExt {
}
```

Imperative OCL constructs – OCL extension

- Loop support – **while, forEach –** (iterates over collection)

- Imperative iterators – powerful, concise

  `Ma->objects()![A]; -- selects single object of kind A`

- Execution control
  - return – usual semantics of exiting operation with a result value
  - break, continue - loops, iterators

- Variable initialization – scoped within block expressions

- Switch – avoids complex if else if ….

- Exceptions – try {…} catch {…} semantics

Black-boxing

Enables to escape the whole transformation/library or its parts that are difficult or impossible to implement in pure QVT.

Black-box transformation

contains only transformation signature and no implementation

(entry point, mapping operations)

```
transformation MMaToMMb(in Ma : MMa, out Mb : MMb);
```

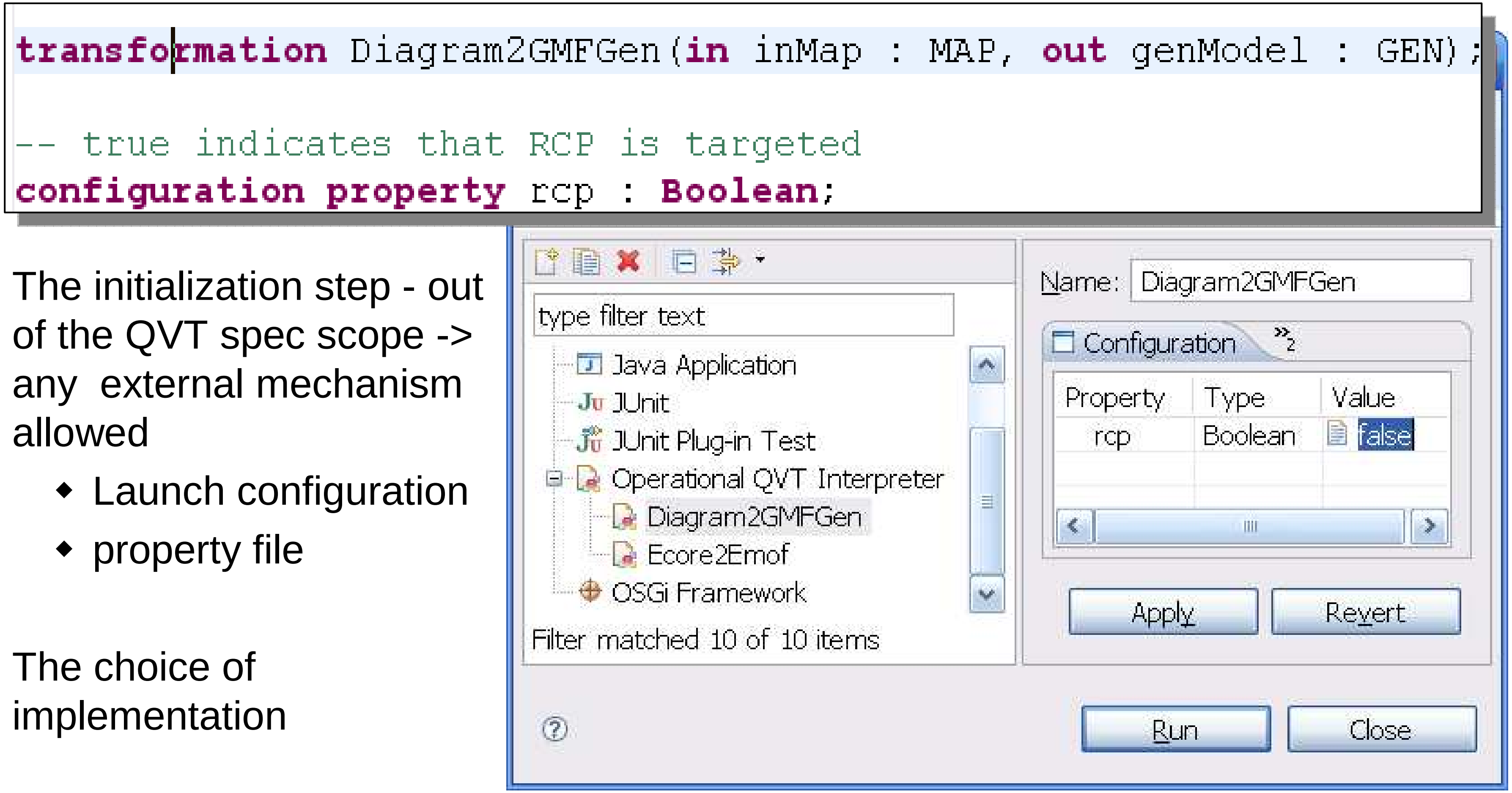
Black-box operation – signature only operation, no body specified -> external

```
mapping A::AtoB() : B;
```

- Compliance points of transformation definition – indicated by the transformation writer
    - **QVT-Operational*** - uses black-box operation
    - **QVT-Operational** - pure QVT language

Configuration properties

- **configuration** qualifier keyword used with module property declaration



```
transformation Diagram2GMFGen(in inMap : MAP, out genModel : GEN);

-- true indicates that RCP is targeted
configuration property rcp : Boolean;
```

- The initialization step - out of the QVT spec scope -> any external mechanism allowed
  - Launch configuration
  - property file
- The choice of implementation

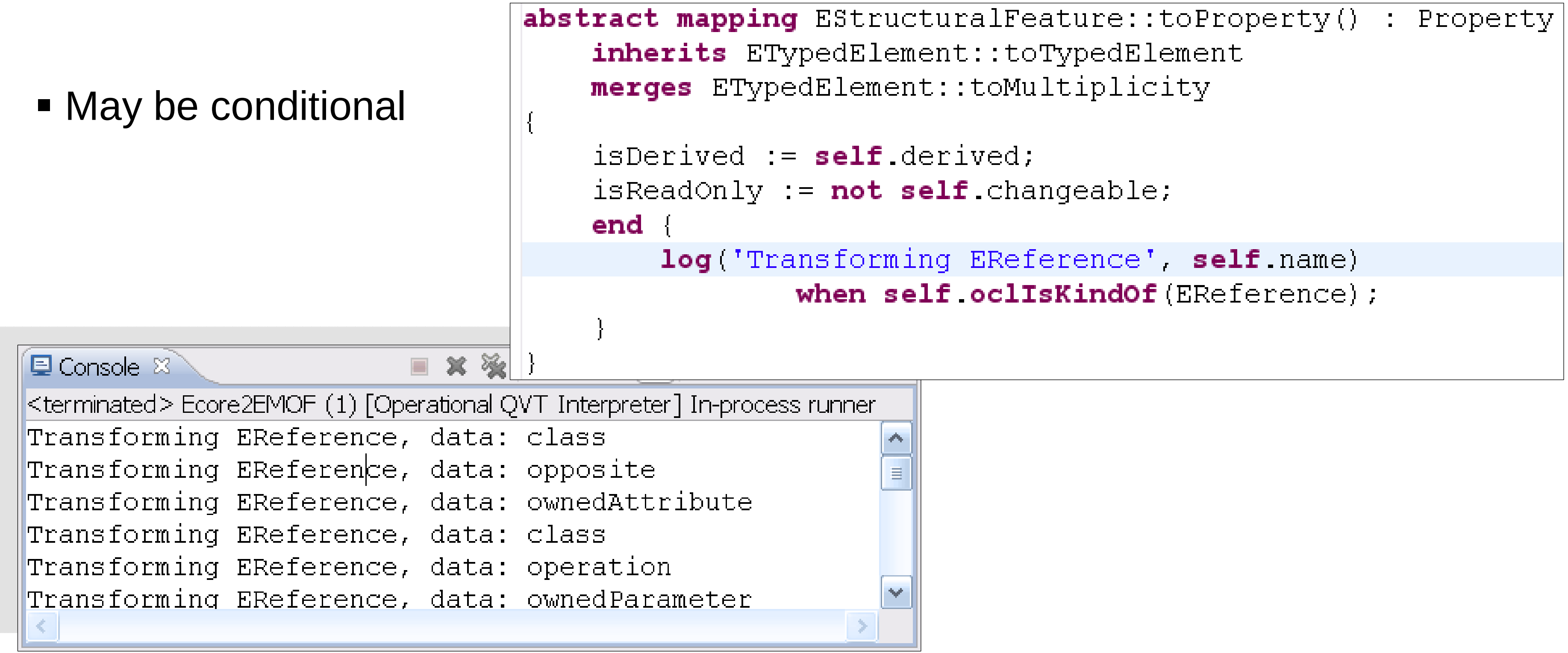
Name: Diagram2GMFGen

Property	Type	Value
rcp	Boolean	false

Filter matched 10 of 10 items

Log expression

- Adds log record entry to the execution environment.
    - **message** text
    - **element** optional, model element associated with the log
    - **level** optional, raw integer value – applicable for filtering
- May be conditional



```
abstract mapping EStructuralFeature::toProperty() : Property
    inherits ETypedElement::toTypedElement
    merges ETypedElement::toMultiplicity
{
    isDerived := self.derived;
    isReadOnly := not self.changeable;
    end {
        log('Transforming EReference', self.name)
                when self.oclIsKindOf(EReference);
    }
}
```

```
<terminated> Ecore2EMOF (1) [Operational QVT Interpreter] In-process runner
Transforming EReference, data: class
Transforming EReference, data: opposite
Transforming EReference, data: ownedAttribute
Transforming EReference, data: class
Transforming EReference, data: operation
Transforming EReference, data: ownedParameter
```

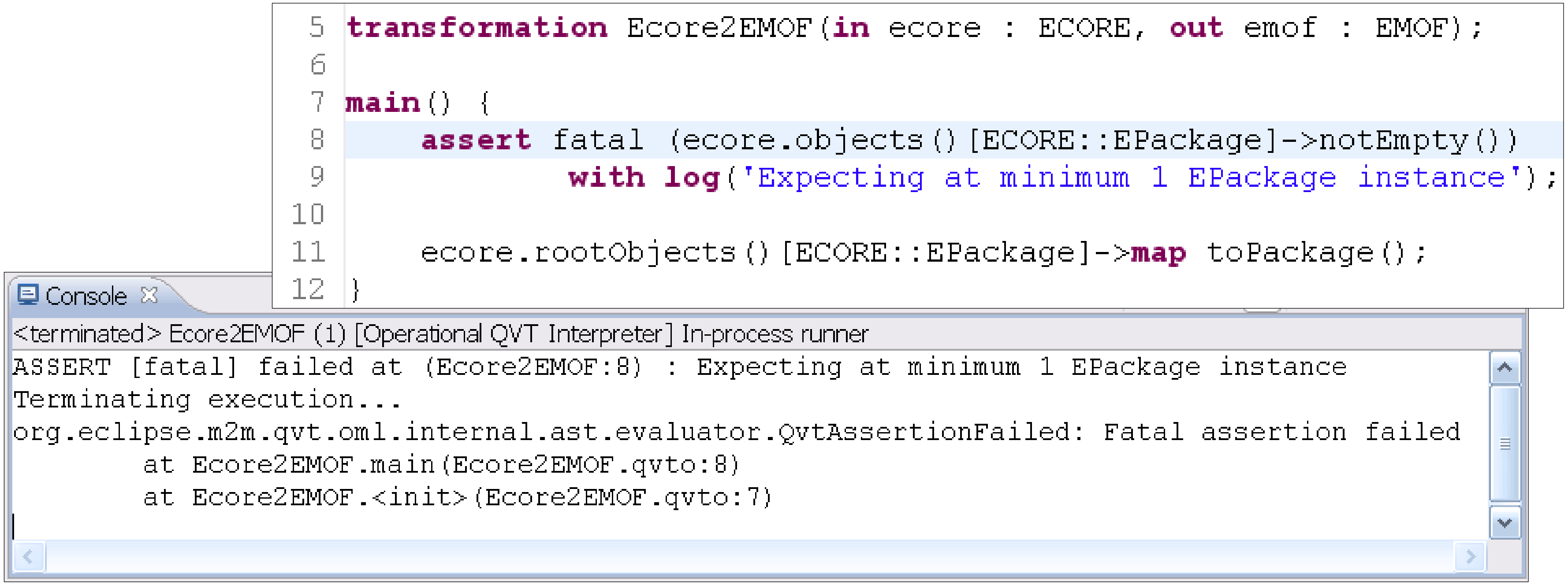
Assertion

Asserts a condition and generates error message in case it does not hold.

- severity level - **warning** | **error** | **fatal**

  fatal - throws exception and transformation execution terminates

- log record - optionally used with log expression



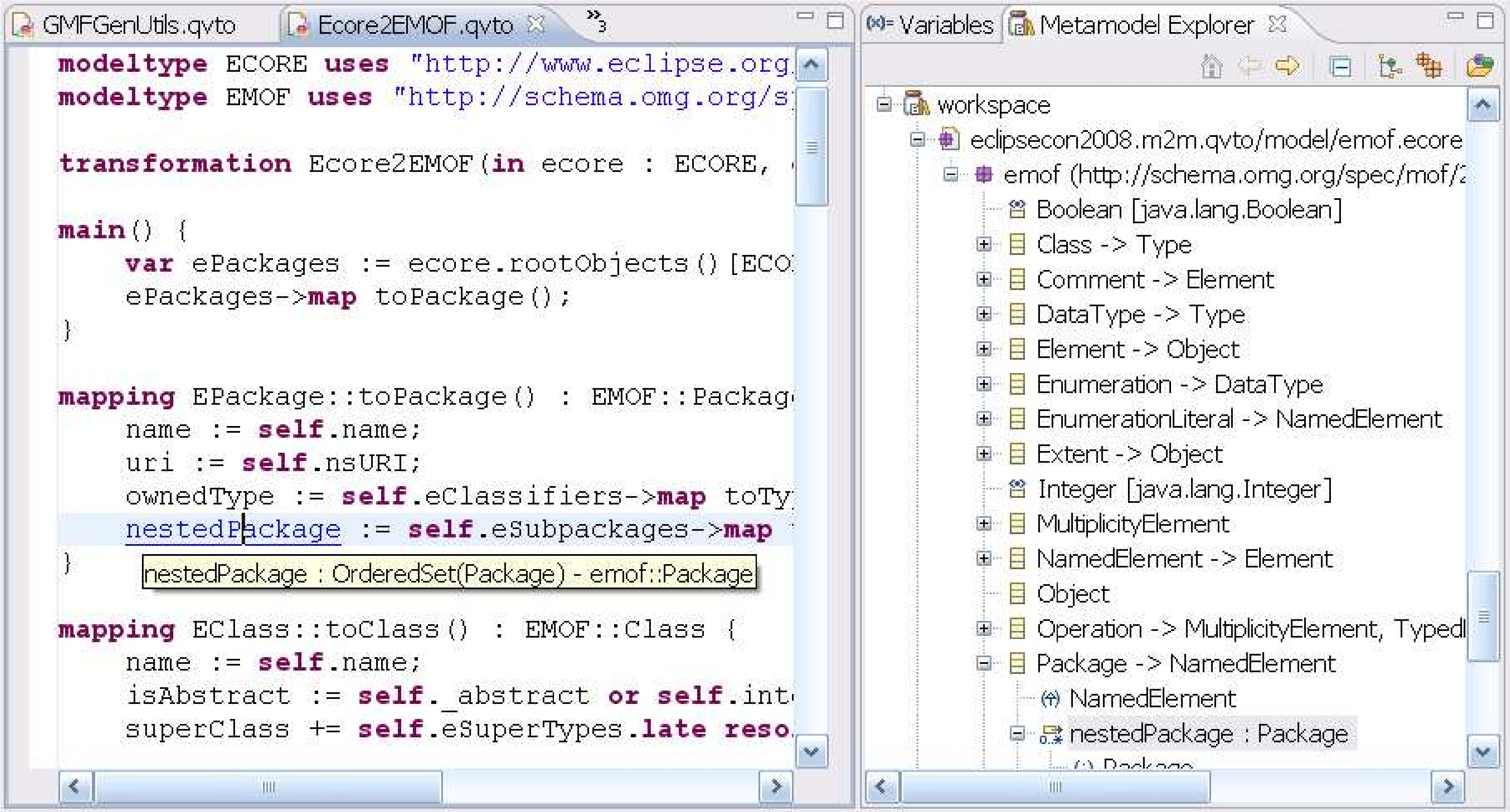
```
 5 transformation Ecore2EMOF(in ecore : ECORE, out emof : EMOF);
 6
 7 main() {
 8     assert fatal (ecore.objects()[ECORE::EPackage]->notEmpty())
 9             with log('Expecting at minimum 1 EPackage instance');
10
11     ecore.rootObjects()[ECORE::EPackage]->map toPackage();
12 }
```

```
<terminated> Ecore2EMOF (1) [Operational QVT Interpreter] In-process runner
ASSERT [fatal] failed at (Ecore2EMOF:8) : Expecting at minimum 1 EPackage instance
Terminating execution...
org.eclipse.m2m.qvt.oml.internal.ast.evaluator.QvtAssertionFailed: Fatal assertion failed
        at Ecore2EMOF.main(Ecore2EMOF.qvto:8)
        at Ecore2EMOF.<init>(Ecore2EMOF.qvto:7)
```

QVTO – where we are?

- Based on MDT OCL
    - reuses OCL metamodels
    - extends OCL parser
    - extends OCL evaluator
- So far, primary focus on concrete syntax, execution and reasonable tooling support
    - AST model with some differences from the spec – legacy reasons
    - concrete syntax – not complete, but major concepts supported
- Next steps
    - complete concrete syntax – executable (except parallel transf. etc)
    - standardize QVT AST -> XMI-Exportable

Editor support – syntax highlight, hovers, hyperlinks

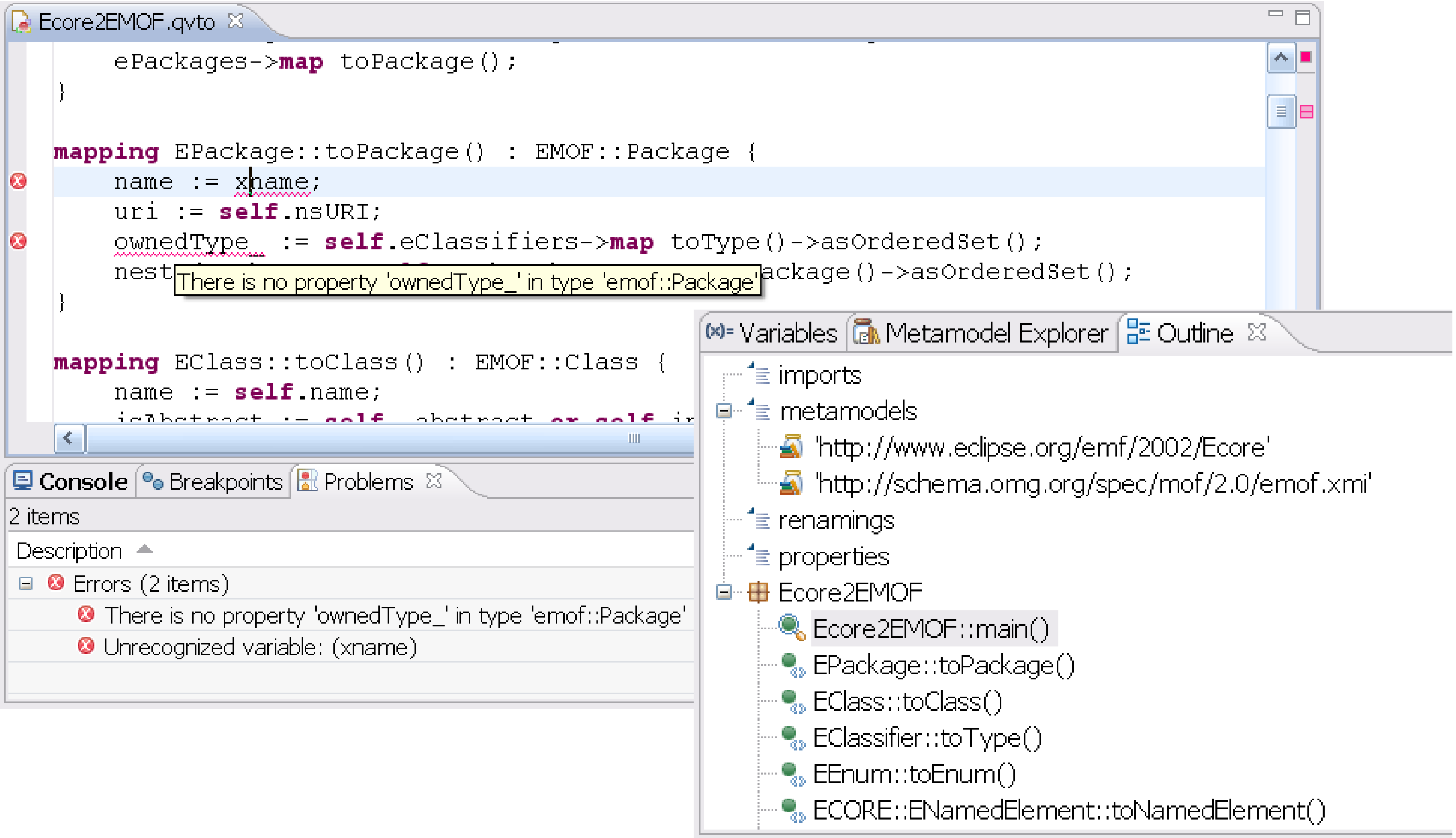


```
modeltype ECORE uses "http://www.eclipse.org
modeltype EMOF uses "http://schema.omg.org/s

transformation Ecore2EMOF(in ecore : ECORE,

main() {
    var ePackages := ecore.rootObjects()[ECO
    ePackages->map toPackage();
}

mapping EPackage::toPackage() : EMOF::Packag
    name := self.name;
    uri := self.nsURI;
    ownedType := self.eClassifiers->map toTy
    nestedPackage := self.eSubpackages->map
}

mapping EClass::toClass() : EMOF::Class {
    name := self.name;
    isAbstract := self._abstract or self.int
    superClass += self.eSuperTypes.late reso
```

```
nestedPackage : OrderedSet(Package) - emof::Package
```

```
workspace
  eclipsecon2008.m2m.qvto/model/emof.ecore
    emof (http://schema.omg.org/spec/mof/
      Boolean [java.lang.Boolean]
      Class -> Type
      Comment -> Element
      DataType -> Type
      Element -> Object
      Enumeration -> DataType
      EnumerationLiteral -> NamedElement
      Extent -> Object
      Integer [java.lang.Integer]
      MultiplicityElement
      NamedElement -> Element
      Object
      Operation -> MultiplicityElement, Typed
      Package -> NamedElement
        NamedElement
        nestedPackage : Package
```

Editor support - annotations, problem markers, outline



```
    ePackages->map toPackage();
}

mapping EPackage::toPackage() : EMOF::Package {
    name := xname;
    uri := self.nsURI;
    ownedType_ := self.eClassifiers->map toType()->asOrderedSet();
    nest                                                ackage()->asOrderedSet();
}

mapping EClass::toClass() : EMOF::Class {
    name := self.name;
```

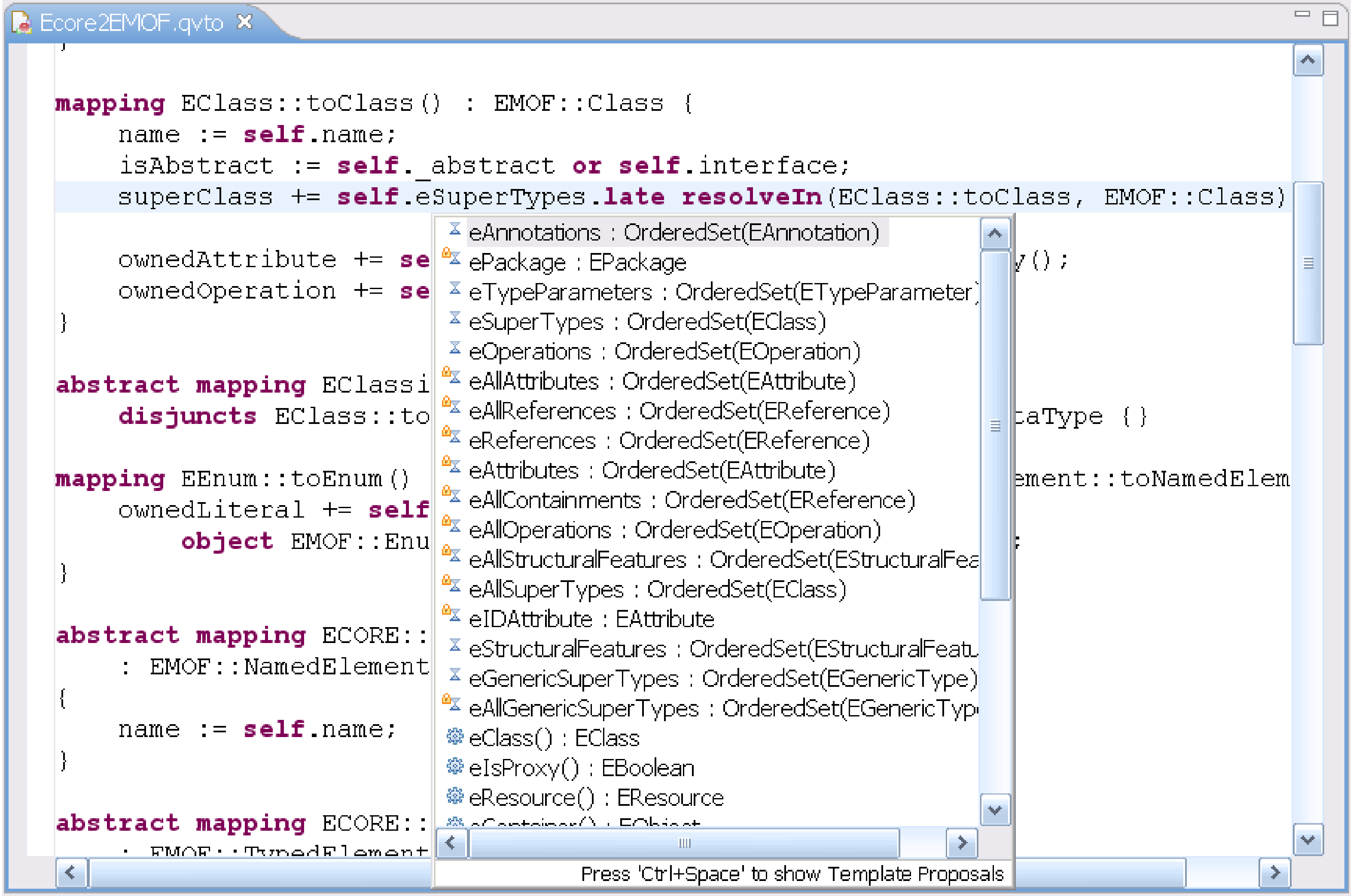
There is no property 'ownedType_' in type 'emof::Package'

2 items

Description
Errors (2 items)
There is no property 'ownedType_' in type 'emof::Package'
Unrecognized variable: (xname)

- imports
- metamodels
  - 'http://www.eclipse.org/emf/2002/Ecore'
  - 'http://schema.omg.org/spec/mof/2.0/emof.xmi'
- renamings
- properties
- Ecore2EMOF
  - Ecore2EMOF::main()
  - EPackage::toPackage()
  - EClass::toClass()
  - EClassifier::toType()
  - EEnum::toEnum()
  - ECORE::ENamedElement::toNamedElement()

Code completion

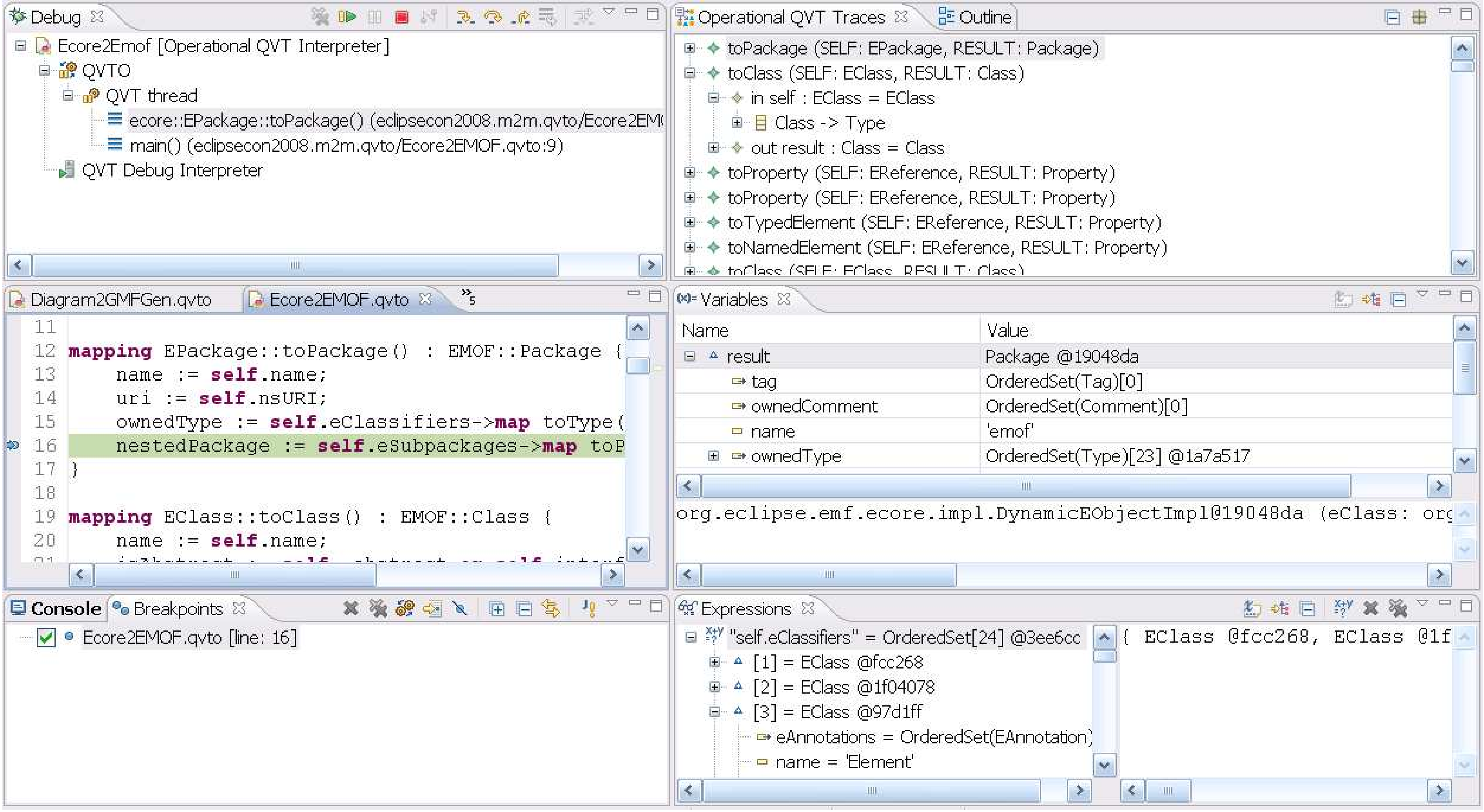


```
}

mapping EClass::toClass() : EMOF::Class {
    name := self.name;
    isAbstract := self._abstract or self.interface;
    superClass += self.eSuperTypes.late resolveIn(EClass::toClass, EMOF::Class)

    ownedAttribute += se                                      y();
    ownedOperation += se
}

abstract mapping EClassi                                      taType {}
    disjuncts EClass::to

mapping EEnum::toEnum()                                       ement::toNamedElem
    ownedLiteral += self
        object EMOF::Enu                                      ;
}

abstract mapping ECORE::
    : EMOF::NamedElement
{
    name := self.name;
}

abstract mapping ECORE::
    : EMOF::TypedElement
```

```
eAnnotations : OrderedSet(EAnnotation)
ePackage : EPackage
eTypeParameters : OrderedSet(ETypeParameter
eSuperTypes : OrderedSet(EClass)
eOperations : OrderedSet(EOperation)
eAllAttributes : OrderedSet(EAttribute)
eAllReferences : OrderedSet(EReference)
eReferences : OrderedSet(EReference)
eAttributes : OrderedSet(EAttribute)
eAllContainments : OrderedSet(EReference)
eAllOperations : OrderedSet(EOperation)
eAllStructuralFeatures : OrderedSet(EStructuralFea
eAllSuperTypes : OrderedSet(EClass)
eIDAttribute : EAttribute
eStructuralFeatures : OrderedSet(EStructuralFeatu
eGenericSuperTypes : OrderedSet(EGenericType)
eAllGenericSuperTypes : OrderedSet(EGenericTyp
eClass() : EClass
eIsProxy() : EBoolean
eResource() : EResource
eContainer() : EObject
```

Press 'Ctrl+Space' to show Template Proposals

Debugging support



Ecore2Emof [Operational QVT Interpreter]
  QVTO
    QVT thread
      ecore::EPackage::toPackage() (eclipsecon2008.m2m.qvto/Ecore2EM
      main() (eclipsecon2008.m2m.qvto/Ecore2EMOF.qvto:9)
  QVT Debug Interpreter

toPackage (SELF: EPackage, RESULT: Package)
toClass (SELF: EClass, RESULT: Class)
  in self : EClass = EClass
    Class -> Type
  out result : Class = Class
toProperty (SELF: EReference, RESULT: Property)
toProperty (SELF: EReference, RESULT: Property)
toTypedElement (SELF: EReference, RESULT: Property)
toNamedElement (SELF: EReference, RESULT: Property)
toClass (SELF: EClass, RESULT: Class)

```

mapping EPackage::toPackage()  : EMOF::Package {
    name := self.name;
    uri := self.nsURI;
    ownedType := self.eClassifiers->map toType(
    nestedPackage := self.eSubpackages->map toP
}

mapping EClass::toClass()  : EMOF::Class {
    name := self.name;
```

Name	Value
result	Package @19048da
tag	OrderedSet(Tag)[0]
ownedComment	OrderedSet(Comment)[0]
name	'emof'
ownedType	OrderedSet(Type)[23] @1a7a517

```
org.eclipse.emf.ecore.impl.DynamicEObjectImpl@19048da (eClass: org
```

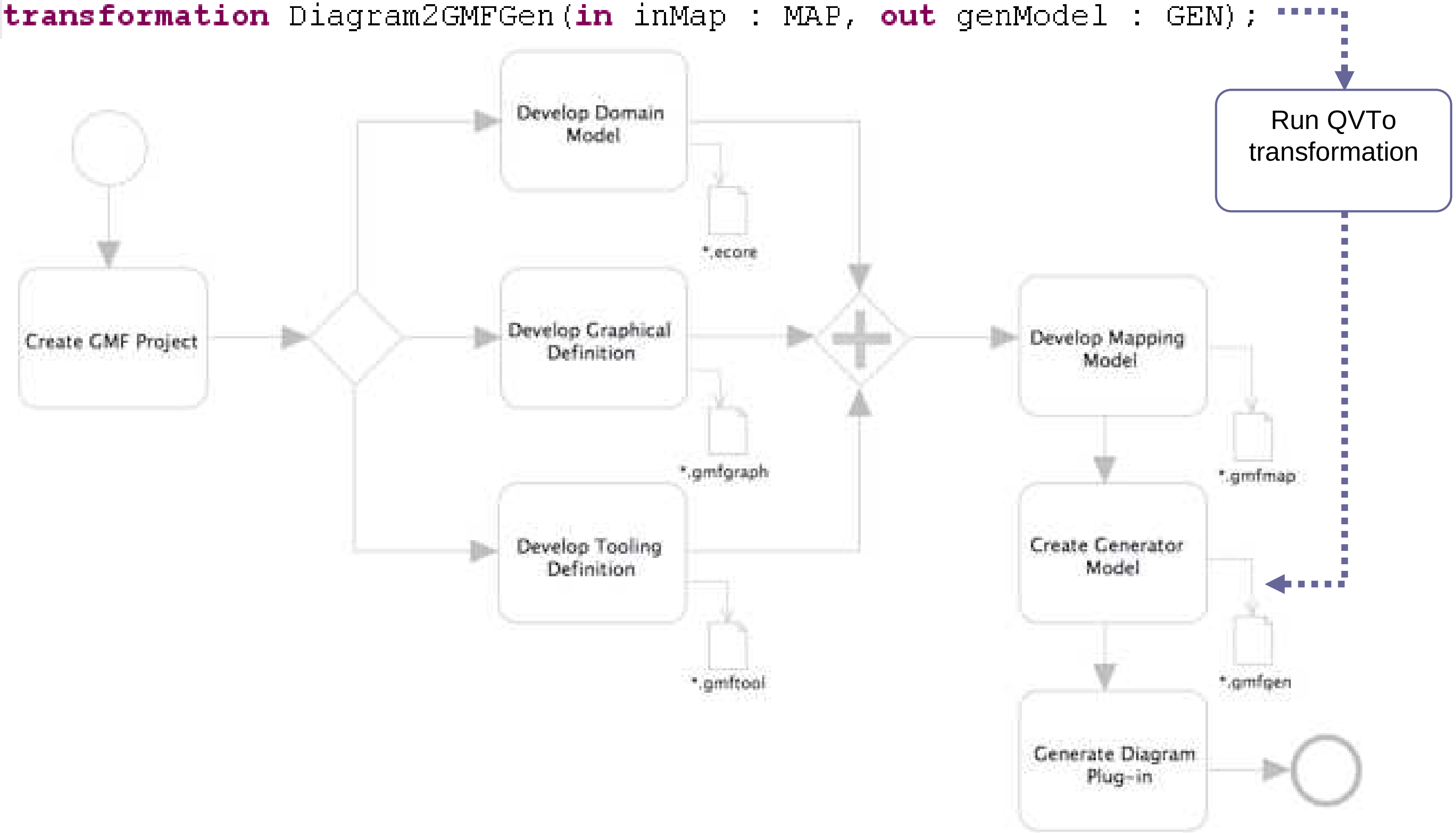
☑ Ecore2EMOF.qvto [line: 16]

"self.eClassifiers" = OrderedSet[24] @3ee6cc
  [1] = EClass @fcc268
  [2] = EClass @1f04078
  [3] = EClass @97d1ff
    eAnnotations = OrderedSet(EAnnotation)
    name = 'Element'

```
{ EClass @fcc268, EClass @1f
```

GMF generator model creation

```
modeltype MAP uses "http://www.eclipse.org/gmf/2006/mappings";
modeltype GEN uses "http://www.eclipse.org/gmf/2006/GenModel";

transformation Diagram2GMFGen(in inMap : MAP, out genModel : GEN);
```


Run QVTo transformation
Develop Domain Model
*.ecore
Create GMF Project
Develop Graphical Definition
*.gmfgraph
Develop Tooling Definition
*.gmftool
Develop Mapping Model
*.gmfmap
Create Generator Model
*.gmfgen
Generate Diagram Plug-in