Definition of a Common Exchange Model

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Available on the WWW at: http://www.iam.unibe.ch/~famoos/InfoExchFormat/

Abstract

This document defines the exchange model for usage by tool prototypes within the FAMOOS reengineering project. The model is based upon the CDIF standard so that it can be transferred via flat ASCII streams.

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1) Introduction

The FAMOOS project (http://www.iam.unibe.ch/~famoos/) aims to develop a reengineering method for transforming object-oriented legacy code into frameworks. The reengineering method itself is defined around a life cycle model (see Figure 1).

1) Requirements Analysis: identifying the concrete reengineering goals
2) Model Capture: documenting and understanding the software system
3) Problem Detection: identifying flexibility and quality problems
4) Problem Resolution: selecting new software architectures to correct the problems
5) Reorganisation: transforming the existing software architecture for a new release
6) Change Propagation: ensuring that all client systems benefit from the new release

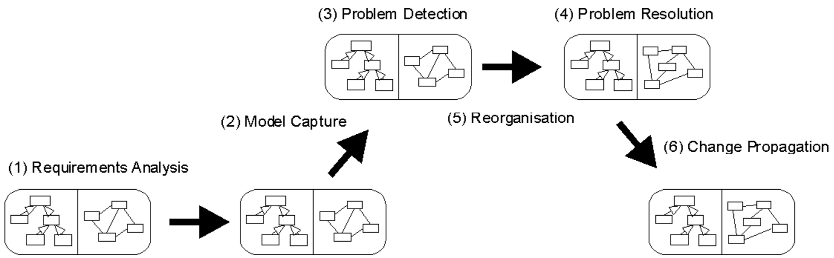


Figure 1: FAMOOS reengineering life cycle

To realise that life cycle, three research areas –which are likely to furnish solutions– have been selected for further investigation

Metrics & Heuristics [DETECTM]
    Applied in phase (3) to identify problems and phase (4) to measure improvement.
Grouping [DOCUM]
    Applied in phase (2) to form software modules and phase (4) to form target architectures.

Reorganisation Operations [REORGOP]
    Applied in phase (5) to perform the actual program transformations and phase (6) to adapt the target software context.

Currently, the FAMOOS partners are building a number of tool prototypes for conducting various experiments within those three research areas. However, the source code available for case studies is written in different implementation languages (C++, Ada and to a lesser extent Java and Smalltalk). To avoid equipping all the tool prototypes with parsing technology for all of the implementation languages, it is necessary to agree on a common information exchange format with language specific extensions (see Figure 2). This document is a specification for such a format.

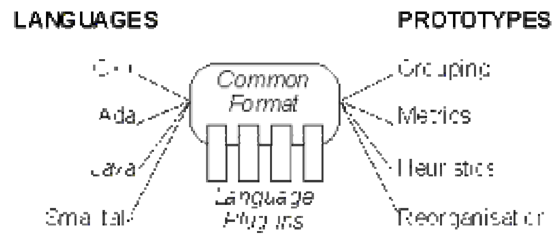


Figure 2: Conception of the Common Exchange Format

2) Requirements Specification

Based on our experiences with the tool prototypes built so far, plus given a survey of the literature on reengineering repositories and code base management systems we specified the following requirement list. The list is split up in two, one part defining requirements concerning the data model, the other part specifying issues concerning the representation.

Data Model

1) *Extensible.* To handle the definition of language plug-ins, the data model must allow extensions with language specific entities and properties. Some tool prototypes may also need to define tool specific properties.

2) *Sufficient basis for metrics, heuristics, grouping and reengineering operations.* To avoid a common denominator that would ineffective for our goals, we set the lower limit for the model to everything that is required to experiment with the tool prototypes.

3) *Readily distillable from source code.* Since it is not our aim to define a model that covers all aspects of all languages, the upper limit to the information the model will contain, is what can be generated by basic code parsing (i.e. parsing without any interpretation of the obtained information, for instance, determining if a relation is an aggregation or a composition). The generated information should be usable by any tool , thus also by language independent tools.

Representation

1) *Easy to generate by available parsing technology.* Since we cannot wait for future developments, we must use parsers available today keeping an eye on short-term evolution. Within the FAMOOS project, parsing technology comes mainly from the FAST library part of the Audit platform. However, there are a number of other viable alternatives: like the SNiFF+ symbol table which is accessible via an API; like Ada compilers which provide standard API's for accessing internal data structures; like the tables generated by Audit which can be transformed in what is needed; like the Java inspection facilities part of java.lang.reflect or even the Java byte code itself; like Smalltalk inspection facilities and parsers that are part of every Smalltalk implementation.

2) *Simple to process.* As the exchange format will be fed into a wide variety of tool prototypes, the format itself should be quite easy to convert into the internal data structures of those prototypes. On top of that, processing by "standard" file utilities (i.e., grep, sed) and scripting languages (i.e., perl, python) must be easy since they may be necessary to cope with format mismatches.

3) *Convenient for querying.* A large portion of reengineering is devoted to the search for information. The representation should be chosen so that it may easily be transformed into an input-stream for querying tools (i.e., spreadsheets and databases).

4) *Human readable.* The exchange format will be employed by (buggy) prototypes. To ease debugging, the format itself should be readable by humans. Especially, references between entities should be by name rather than by identifiers bearing no semantics.

5) *Allows combination with information from other sources.* Although most of the data model will be extracted from source code, we expect that other origins can provide input as well. Especially CASE tools with design diagrams (e.g., TDE or Rational/Rose) are likely candidates. Thus, the representation should allow merging information from other origins. Note that —just like with the "human readable" requirement— this implies that references between entities should be by name rather than by identifiers bearing no semantics.

6) *Supports industry standards.* Since the tool prototypes must be utilised within an industry context, they must integrate with whatever tools already in use. Ad hoc exchange formats (even when they can be translated with scripts) hinder such integration, and --when available-- the representation should favour an industry standard.

3) CDIF Transfer Format

We have adopted CDIF [CDIF94a] as the basis for the information exchange of information in the FAMOOS exchange model [EVALCDIF]. CDIF is an industrial standard for transferring models created with different tools. The main reasons for adopting CDIF are, that firstly it is an industry standard, and secondly it has a standard plain text encoding which tackles the requirements of convenient querying and human readability. Next to that the CDIF framework supports the extensibility we need to define our model and language plug-ins. More information concerning the CDIF standard can be found at http://www.cdif.org/.

4) The Data Model

4.1. The Core Model

The core model (shown in Figure 3) specifies the entities and relations that can and should be extracted immediately from source code[1].

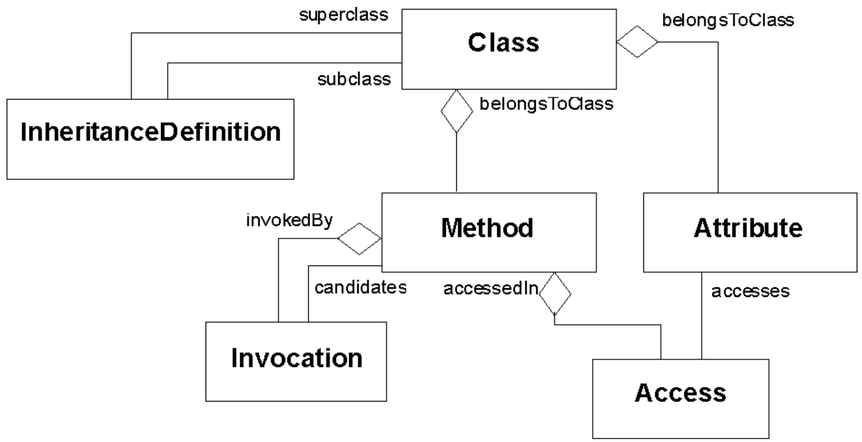


Figure 3: The Core Model

The core model consists of the main OO entities, namely `Class`, `Method`, `Attribute` and `InheritanceDefinition`. For reengineering , we need the other two, the associations `Invocation` and `Access`. An `Invocation` represents the definition of a `Method` calling another `Method`[2] and an `Access` represents a `Method` accessing an `Attribute`[3]. These abstractions are needed for reengineering tasks such as dependency analysis, metrics computation and reengineering operation. Typical questions we need answers for are: "are entities strongly coupled?", "which methods are never invoked?", "I change this method. Where do I need to change the invocations on this method?".

4.2. The complete model

The structure of the complete model is shown in Figure 4. `Object`, `Property`, `Entity` and `Association` are made available to handle the extensibility requirement (see "2) Requirements Specification" - p.2). For specifying language plug-ins, it is allowed to define language specific Objects, plus it is allowed to add language specific attributes to existing Objects. Tool

[1] The model doesn't consist of abstractions for packages at this point. This will be integrated in the future.

[2] Actually, in the complete model an Invocation is more general: it is about behavioural entities (such as methods and functions) calling other behavioural entities.

[3] In the complete model an Access is about a behavioural entity accessing a structural entity (such as attributes and global variables).

prototypes are more restricted in extensions to the model: they can define tool specific `Properties` for existing Objects. Next to that, they can add attributes to existing Objects, but they cannot extend the repertoire of entities and associations. For a complete description of how to extend the model, see appendix "B. How to extend the model" - p.27. The abstract classes `StructuralEntity` and `BehaviouralEntity` are needed by the associations.

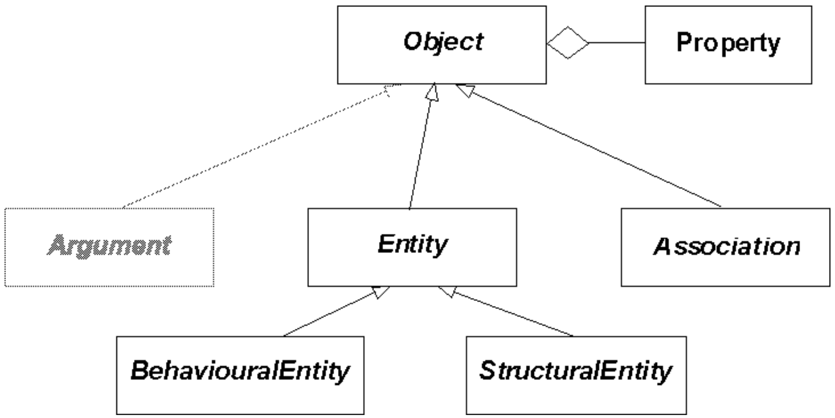


Figure 4: Basic structure of the complete model

In the following sections we describe the different entities with their attributes, and how these entities are represented in the CDIF transfer format. Some of the attributes might not appear in the CDIF format. Mandatory attributes always appear. Optional attributes that do not appear, have either a default value or are unknown.

4.3. Basic Data Types

Besides the usual primitive data types (String, Integer, Boolean…) we have a number of extra data types in our model that are considered "basic". These are `Name`, `Qualifier` and `Index`:

- `Name` vs. `Qualifier`
  A `Name` is a string that bears semantics inside the model, while a `Qualifier` is a string that gets its semantics from outside the model. A `String` does not bear any semantics. For instance, a `uniqueName` may be used to refer to another object, hence bears semantics inside the model. However, a `sourceAnchor` will store some information that must be interpreted by applications outside the model, hence is a qualifier. Finally, a comment line is a string, since it does not bear any semantics understandable by a computer. In CDIF these types are simply represented by Strings, or TextValues if they are multi-valued (see appendix "A. Clarifications on the CDIF Encoding" - p.26 for a description of multi-valued strings in CDIF).

- `Index`
  An Index represents a position in some sequence. Indices always have a base of 1. In CDIF this type is represented by an integer.

4.4. Level of Extraction

The core model contains entities that not all parsers may provide. Next to that, some tools do not always need all of this information (e.g. a metrics tool might not need `Invocation` and `Access`, because many metrics can already be gathered from `Class` and `Method` alone). To allow "incomplete" models, we introduce the *level of extraction*.

Basically, the level of extraction is an integer, telling how much of the core model is actually extracted. In principle, the higher the number, the more information is available. The levels are set up in such a way that no information is available on a level that needs information from higher levels (for instance, `Access` is not usable if there are no `Attribute`'s available). Next to that, it is possible that on the higher levels parts of the information aren't necessary for a certain task, or simply not computable by a certain tool. Therefore it is allowed to only provide parts of the information on the levels 3 and 4 (designated by the "+/-").

Table 1 gives an overview of the levels of extraction.

Level 1	`Class, InheritanceDefinition, Method.` Level 1 is the minimum model that parsers should be able to provide and corresponds with what is usually understood as the interface of a class.
Level 2	Level 1 + `Attribute`
Level 3	Level 2 +/- `Access` +/- `Invocation`
Level 4	Level 3 +/- `instances of Argument` +/- `instances of BehaviouralEntity`

Table 1: Levels of Extraction

4.5. The basic classes Object, Entity and Association

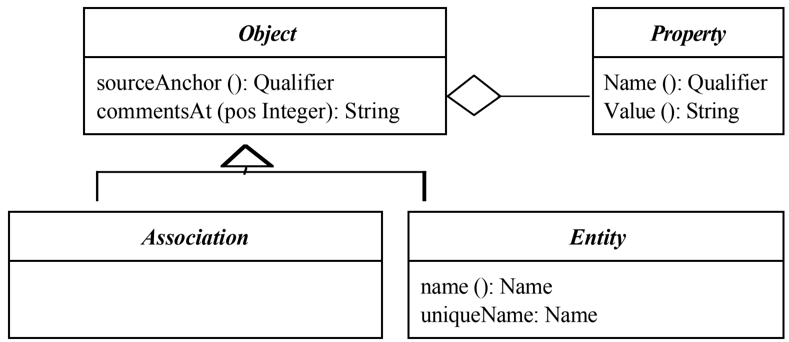


Figure 5: The basic classes Object, Entity and Association

As stated in section 4.2, the classes `Object`, `Entity`, `Association` and `Property` are added to provide extensibility to the model. The attributes of the basic classes are:

- `sourceAnchor: Qualifier; optional`
  Identifies the location in the source where the information is extracted.
  The exact format of the qualifier is dependent on the source of the information. Usually, it will be an anchor in a source file, in which case the following format should be used

  ```
  file "<filespec>" start <start_index> stop <stop_index>.
  ```

  Where <filespec> is a string holding the name of the source-file in an operating system dependent format (preferably a filename relative to some project directory). Note that filenames may contain spaces and double quotation marks. A double quotation mark in a filename should be escaped with a `\"`. <start_index> and <stop_index> are indices starting at 1 and holding the beginning/ending character position in the source file.
  Extra position indices or whole source anchors may be added to handle anchors in files that may need to be displayed with external editors. For instance, the line and column of the character (`startline`, `startcol`, `stopline`, `stopcol`). Or the negative offset counting from the end of the file instead of from the beginning (`negstart`, `negstop`). In CDIF a basic source anchor looks as follows (delimited with a '|', see appendix "A. Clarifications on the CDIF Encoding" - p.26 for a description of multi-valued strings in CDIF):

  ```
  (sourceAnchor #[file "factory.h" start 260 end 653|]#)
  ```

- `comments: 0..N String; optional`
  Entities and associations may own a number of comments, where developers and tools store textual information about the object. In CDIF we represent this with a CDIF TextValue, where the blocks are delimited by a '|' (see appendix "A. Clarifications on the CDIF Encoding" - p.26 for a description of multi-valued strings in CDIF):

  ```
  (comments #[commentLines|]#,#[commentLines|]#,...)
  ```

Entities and associations may own a number of properties where extensions of the core model may be stored. A `Property` has the following attributes:

- `name: Qualifier; mandatory`
  Is a string that identifies a `Property`.

- `value: String; mandatory`
  Contains the value of the property. The meaning of the value is not defined within this model.

CDIF example showing a class `Widget` with a `Property` containing the value 5 for some number-of-methods metric[4]. They are related by the relationship `HasProperty`:

```
(Class ENT001
     (name "Widget")
     ....
)
```

[4] Every CDIF entity has a unique identifier which is local for a information exchange. In the presented example these identifiers are: ENT001, PR005 and REL003 for respectively the `Class` instance, the `Property` instance and the `HasProperty` relation instance.


```
(Property PR005
     (name  "metric_NOM")
     (value #[5]#)
)

(Entity.HasProperty.Property REL003 ENT001 PR005)
```

To enable a global referencing scheme based on names, the key classes in the model should respect the minimal interface of `Entity`.

- `name: String; mandatory`
  Is a string that provides some human readable reference to an entity.

- `uniqueName: String; mandatory`
  Is a string that is computed based on the name of the entity. Each class must define its specific formula. The uniqueName serves as an external reference to that entity and must be unique for all entities in the model.

4.6. Core Entity: Class

Class
isAbstract (): Boolean scopeQualifier (): Qualifier

Figure 6: Class

A `Class` represents the definition of a class in source code. What exactly constitutes such a definition is a language dependent issue. Besides the attributes inherited from `Entity`, it has the following attributes:

- `isAbstract: Boolean; optional`
  Is a predicate telling whether the class is declared abstract. Abstract classes are important in OO modelling, but how they are recognised in source code is a language dependent issue.

- `scopeQualifier: Qualifier; optional`
  Is a string with a language dependent interpretation, that defines the scope of a class. A null scopeQualifier is allowed, it means that the class has global scope. The scopeQualifier concatenated with the name of the class must provide a unique name for that class within the model.

- formula for `uniqueName`:

  ```
  if isNull (scopeQualifier(class)) then
       uniqueName (class) = name (class)
     else
       uniqueName (class) = scopeQualifier (class)
         + "::" + name (class)
  ```

CDIF Example of a non-abstract class Widget with global scope:

```
(Class FM1
        (name "Widget")
        (uniqueName "Widget")
        (isAbstract -FALSE-)
        (sourceAnchor #[file "factory.h" start 260 end 653|]#)
)
```

4.7. Core Entity: Method

Method
belongsToClass (): Name hasClassScope (): Boolean isAbstract (): Boolean isConstructor (): Boolean
accessControlQualifier (): Qualifier signature (): Qualifier isPureAccessor (): Boolean declaredReturnType (): Qualifier declaredReturnClass (): Name

Figure 7: Method

A `Method` represents the definition in source code of an aspect of the behaviour of a class. What exactly constitutes such a definition is a language dependent issue. Besides the inherited attributes, it has the following attributes:

- `belongsToClass: Name; mandatory`
  Is a name referring to the class owning the method. It uses the uniqueName of the class as a reference.
- `hasClassScope: Boolean; optional`
  Is a predicate telling whether the method has class scope (i.e., invoked on the class) or instance scope (i.e., invoked on an instance of that class).
- `isAbstract: Boolean; optional`
  Is a predicate telling whether the method is declared abstract. Abstract methods are important in OO modelling, but how they are recognised in source code is a language dependent issue.
- `isConstructor: Boolean; optional`
  Is a predicate telling whether the method is a constructor. A constructor is a method that creates an (initialised) instance of the class it is defined on. Thus a method that creates an instance of another class is not considered a constructor. How constructor methods are recognised in source code is a language dependent issue.
- `accessControlQualifier: Qualifier; optional`
  See definition of `StructuralEntity` (see p. 18).

- `signature: Qualifier; mandatory`
  See definition of `StructuralEntity` (see p. 18).
- `isPureAccessor: Boolean; optional`
  See definition of `StructuralEntity` (see p. 18).
- `declaredReturnType: Qualifier; optional`
  See definition of `StructuralEntity` (see p. 18).
- `declaredReturnClass: Name; optional`
  See definition of `StructuralEntity` (see p. 18).
- formula for `uniqueName`:

```
uniqueName (method) = belongsToClass (method) +
  "." + signature (method)
```

CDIF Example (constructor for a class `Widget. This method has no returntype and therefore also no "returnclass", hence are both attributes empty`):

```
(Method FM2
        (name "Widget")
        (belongsToClass "Widget")
        (sourceAnchor #[file "factory.h" start 321 end 326|]#)
        (accessControlQualifier "public")
        (hasClassScope -FALSE-)
        (signature "Widget()")
        (isAbstract -FALSE-)
        (declaredReturnType "")
        (declaredReturnClass "")
        (uniqueName "Widget.Widget()")
)
```

4.8. Core Entity: Attribute

Attribute
belongsToClass (): Name accessControlQualifier (): Qualifier hasClassScope (): Boolean
declaredType (): Qualifier declaredClass (): Name

Figure 8: Attribute

An `Attribute` represents the definition in source code of an aspect of the state of a class. What exactly constitutes such a definition is a language dependent issue. Besides the attributes inherited from `Entity`, it has the following attributes:

- `belongsToClass: Name; mandatory`
  Is a name referring to the class owning the attribute. It uses the uniqueName of the class as a reference.

- `accessControlQualifier: Qualifier; optional`
  Is a string with a language dependent interpretation, that defines who is allowed to access it (for instance, 'public', 'private'…).

- `hasClassScope: Boolean; optional`
  Is a predicate telling whether the attribute has class scope (i.e., shared memory location for all instances of the class) or instance scope (i.e., separate memory location for each instance of the class).

- `declaredType: Qualifier; optional`
  See definition of `StructuralEntity` (see p.18).

- `declaredClass: Name; optional`
  See definition of `StructuralEntity` (see p.18).

- formula for `uniqueName`:

```
uniqueName (attribute) = belongsToClass (attribute) +
  "." + name (attribute)
```

CDIF Example of a private attribute `wTop` in class `Widget`:

```
(Attribute FM22
        (name "wTop")
        (belongsToClass "Widget")
        (sourceAnchor #[file "factory.h" start 281 end 284|]#)
        (declaredType "int")
        (declaredClass "")
        (accessControlQualifier "private")
        (uniqueName "Widget.wTop")
)
```

4.9. Core Association: InheritanceDefinition

InheritanceDefinition
subclass (): Name superclass (): Name accessControlQualifier (): Qualifier index (): Index

Figure 9: InheritanceDefinition

An `InheritanceDefinition` represents the definition in source code of an inheritance association between two classes. One class then plays the role of the superclass, the other plays the role of the subclass. What exactly constitutes such a definition is a language dependent issue. Besides the attributes inherited from `Association`, it has the following attributes:

- `subclass: Name; mandatory`
  Is a name referring to the class that inherits. It uses the uniqueName of the class as a reference.

- `superclass: Name; mandatory`
  Is a name referring to the class that is inherited from. It uses the uniqueName of the class as a reference.

- `accessControlQualifier: Qualifier; optional`
  Is a string with a language dependent interpretation, that defines how subclasses access their superclasses (for instance, 'public', 'private'…).

- `index: Index; optional`
  In languages with multiple inheritance, this is the position of the superclass in the list of superclasses of one subclass. Usually this will have a null value, but it may be necessary for OO languages with multiple inheritance that resolve name collisions via the order of the superclasses (i.e., CLOS).

CDIF Example of an inheritance relationship between `Scrollbar` and `Widget`:

```
(InheritanceDefinition FM27
        (subclass "ScrollBar")
        (superclass "Widget")
        (accessControlQualifier "public")
        (index 1)
)
```

4.10. Core Association: Access

Access
accesses (): Name accessedIn (): Name isAccessLValue (): Boolean

Figure 10: Access

A `Access` represents the definition in source code of a `BehaviouralEntity` accessing a `StructuralEntity`. Depending on the level of extraction (see Table 1, p. 6), that `StructuralEntity` may be an attribute, a local variable, an argument, a global variable…. What exactly constitutes such a definition is a language dependent issue. Besides the attributes inherited from `Association`, it has the following attributes:

- `accesses: Name; mandatory`
  Is a name referring to the variable being accessed. It uses the uniqueName of the variable as a reference.

- `accessedIn: Name; mandatory`
  Is a name referring to the method doing the access. It uses the uniqueName of the method as a reference.

- `isAccessLValue: Boolean; optional`
  Is a predicate telling whether the value was accessed as Lvalue, i.e. a location value or a value on the left side of an assignment. When the predicate is true, the memory location denoted by the variable might change it value; false means that the contents of the

memory location is read; null means that it is unknown.
Note that LValue is the inverse of RValue.

Example of `print()` accessing `wTop`:

```
virtual print () { cout << "top of widget " << wTop; };
```

In CDIF:

```
(Access FM18
        (accesses "Widget.wTop")
        (accessedIn "Widget.print()")
)
```

4.11. Core Association: Invocation

Invocation
invokedBy (): Name invokes (): Qualifier base (): Name candidatesAt (pos Integer): Name

Figure 11: Invocation

A `Invocation` represents the definition in source code of a `BehaviouralEntity` invoking another `BehaviouralEntity`. What exactly constitutes such a definition is a language dependent issue. It is important to note that due to polymorphism, there exists at parse time a one-to-many relationship between the invocation and the actual entity invoked: a method, for instance, might be defined on a certain class, but at runtime actually invoked on an instance of a subclass of this class. This explains the presence of the `base` attribute and the `candidates` aggregation.

Besides the attributes inherited from `Association`, it has the following attributes:

- `invokedBy: Name; mandatory`
  Is a name referring to the `BehaviouralEntity` doing the invocation. It uses the uniqueName of the entity as a reference.

- `invokes: Qualifier; mandatory`
  Is a qualifier holding the signature of the `BehaviouralEntity` invoked. Due to polymorphism, the signature of the invoked `BehaviouralEntity` is not enough to assess which `BehaviouralEntity` is actually invoked. Further analysis based on the arguments is necessary. Concatenated with the `base` attribute this attribute constitutes the unique name of a behavioural entity.

- `base: Name; optional`
  Is the unique name of the entity where the invoked entity is defined on. Null means unknown and an empty string means the attribute has no base (the invoked entity may be a global function). Together with the `invokes` attribute, this attribute constitutes the unique name of a behavioural entity.

- `candidates: 0 .. N Name; optional`
  Is a multi-valued attribute holding a number of names of `BehaviouralEntities`. Each name refers to a `BehaviouralEntity` that may be the actual one invoked at run-time. See appendix "A. Clarifications on the CDIF Encoding" - p.26 for a description of multi-valued strings in CDIF.

CDIF Example. The method `Widget.print()` is invoked according to the source code. The actual method invoked at runtime, however, could be the `print()` method of one of the subclasses `MotifWidget` or `SwingWidget`:

```
(Invocation FM35
        (invokedBy "ScrollBar.print()")
        (invokes "print()")
        (base "Widget")
        (candidates  #[Widget.print()|]#,
                     #[MotifWidget.print()|]#,
                     #[SwingWidget.print()|]#)
)
```

4.12. Argument, ComplexExpression & SimpleAccess

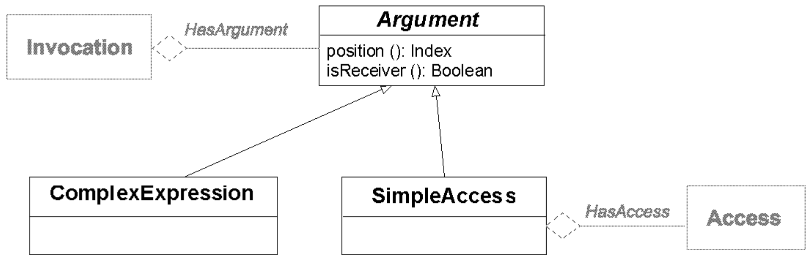


Figure 12: Argument, ComplexExpression & SimpleAccess

An `Argument` represents the passing of an argument when invoking a `BehaviouralEntity`. What exactly constitutes such a definition is a language dependent issue. The model distinguishes between two kind of arguments, a complex expression or a simple access. The former means that some expression is passed, in that case the contents of the expression is not further specified. The latter means that some `StructuralEntity` is passed, in which case an access is maintained.

Besides the attributes inherited from `Association`, it has the following attributes:

- `position: Index; mandatory`
  The position of the argument in the list of arguments.

- `isReceiver: Boolean; optional`
  Is a predicate telling whether this argument plays the role of the receiver in the containing invocation.

Example:

```
Widget.print () {
        call(wTop);
}
```

CDIF:

```
(SimpleAccess FM35
        (position 1)
        (isReceiver -FALSE-)
)

(Access FM89
        (accesses "Widget.wTop")
        (accessedIn "Widget.print()")
)

(Invocation FM101
        (invokedBy "Widget.print()")
        (invokes "call(int)")
)

(SimpleAccess.HasAccess.Access FM107 FM35 FM89)

(Invocation.HasArgument.Argument FM108 FM101 FM35)
```

4.13. BehaviouralEntity Hierarchy

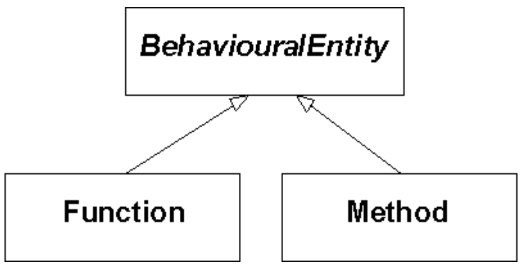


Figure 13: BehaviouralEntity Hierarchy

The entities that define behaviour in our model are all subclasses of `BehaviouralEntity`.

4.14. BehaviouralEntity

BehaviouralEntity
accessControlQualifier (): Qualifier signature (): Qualifier isPureAccessor (): Boolean declaredReturnType (): Qualifier declaredReturnClass (): Name

Figure 14: BehaviouralEntity

A `BehaviouralEntity` represents the definition in source code of a behavioural abstraction, i.e. an abstraction that denotes an action rather than a part of the state. Subclasses of this

class represent different mechanisms for defining such an entity. Besides the attributes inherited from `Entity`, it has the following attributes:

- `accessControlQualifier: Qualifier; optional`
  Is a string with a language dependent interpretation, that defines who is allowed to invoke it (for instance, 'public', 'private'…).

- `signature: Qualifier; mandatory`
  Is a string that allows to uniquely distinguish a behavioural entity. This is necessary because there exist OO languages (i.e., C++, Java) that allow to overload methods, so that the same method name may be associated with different parameter lists, each with its own method body. The way a signature string is composed is language dependent, but it should at least include the name of the method. The UML [Booc96a] compliant notation will be used, which will typically look like "`package::subpackage::classname.methodname(parameters)`" . The signature is not allowed to contain any spaces[5].

- `isPureAccessor: Boolean; optional`
  Is a predicate telling whether the behavioural entity is a pure accessor. There are two kinds of accessors, a reader accessor and a writer accessor. A pure reader accessor is an entity with a single receiver parameter, only returning the value of an attribute of the class the method is defined on. A pure writer accessor is a method with one receiver parameter and one value parameter, only storing the value inside the attribute of a class. How accessor methods are recognised in source code is a language dependent issue.

- `declaredReturnType: Qualifier; optional`
  Is a qualifier that via interpretation outside the model refers to the type of the returned object. Typically this will be a class, a pointer or a primitive type (e.g. "`int`" in Java). `declaredReturnType` is null if the return type is not known or the empty string (i.e. "") if the `BehavourialType` doesn't have a return type[6] (for instance, the C++ void). How the declared return type may be recognised in source code and how the return type matches to a class or another type are language dependent issues.

- `declaredReturnClass: Name; optional`
  The class that is implicit in the `declaredReturnType`. For example, in C++ the `declaredReturnClass` of Class* m() is Class. This attribute is particularly useful for dependency analysis and should therefore be added in case it is easily extractable from source code.
  `declaredReturnClass` is null if the declaredClass is unknown or the empty string (i.e. "") if it is known that the `declaredReturnType` doesn't implicitly consist of a Class, but something else such as a primitive type.

---

[5] A signature and a scopeQualifier are not allowed to contain any spaces. This makes it easier to compare and parse these attributes and attributes that are derived from them.

[6] This is consistent with UML 1.1 [Booc96a]. We don't use "void", because this doesn't work for, for instance, Smalltalk, where it is possible to define a class called "void".

4.15. Function

Function
scopeQualifier (): Qualifier

Figure 15: Function

A `Function` represents the definition in source code of an aspect of global behaviour. What exactly constitutes such a definition is a language dependent issue. Besides the inherited attributes, it has the following attributes:

- `scopeQualifier: Qualifier; optional`
  Is a string with a language dependent interpretation, that defines a possible scope of the variable. A null `scopeQualifier` is allowed, it means that the variable must not be explicitly imported before using it. The scope qualifier concatenated with the name of the function must provide a unique name for that function within the model. Scope qualifiers are not allowed to contain any spaces[5].

- formula for `uniqueName`:

```
uniqueName (method) = scopeQualifier (function) +
  "::" + signature (function)
```

CDIF Example (of a global function "testFactory" in sub package "test" of package "widgetfactory"):

```
(Function FM2
        (name "testFactory")
        (sourceAnchor #[file "factory.h" start 321 end 326|]#)
        (accessControlQualifier "public")
        (signature "testFactory()")
        (scopeQualifier "widgetfactory::test")
        (declaredReturnType "")
        (declaredReturnClass "")
        (uniqueName "widgetfactory::test::testFactory()")
)
```


4.16. StructuralEntity Hierarchy

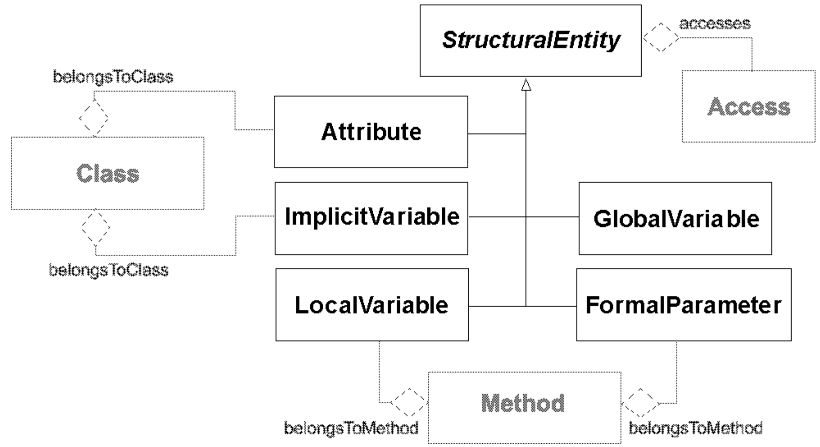


Figure 16: StructuralEntity Hierarchy

All possible variable definitions are subclasses of the class `StructuralEntity`. `StructuralEntity` itself participates in the `Access` association.

4.17. StructuralEntity

StructuralEntity
declaredType (): Qualifier declaredClass (): Name

Figure 17: StructuralEntity

A `StructuralEntity` represents the definition in source code of a structural entity, i.e. it denotes an aspect of the state of a system. The different kinds of structural entities mainly differ in lifetime: some have the same lifetime as the entity they belong to, e.g. an attribute and a class, some have a lifetime that is the same as the whole system, e.g. a global variable. Subclasses of this class represent different mechanisms for defining such an entity. Besides the attributes inherited from `Entity`, it has the following attributes:

- `declaredType: Qualifier; optional`
  Is a qualifier that via interpretation outside the model refers to the type of the returned object. `declaredType` is null if the type is unknown or the empty string (i.e. "") if the `StructuralType` doesn't have a return type (e.g. "void" in C++).
  Note that we need a language dependent interpretation to link a type name to a class name, because in most OO languages, types are not always equivalent to a class. How the declaredType may be recognised in source code and how the type matches to a class are language dependent issue.

- `declaredClass: Name; optional`
  The class that is implicit in the declaredType. The declaredType might be the class itself, but might also be a pointer to a class (for instance, Class* in C++) or a primitive type (such as "`int`" in Java), or something else depending on the language. The declaredClass will contain the class which is designated already by the declaredType, or the class where the declaredType points to, null if it is unknown if there is an implicit class in the declared type, and the empty string (i.e. "") if it is known that there is no implicit class in the declared type. What exactly is the relationship between declaredClass and declaredType is language-dependent.
  Note that this is useful information for, for instance, dependency analysis (a requirement for this model). Therefore it appears in this model.

4.18. GlobalVariable

GlobalVariable
scopeQualifier (): Qualifier

Figure 18: GlobalVariable

A `GlobalVariable` represents the definition in source code of a variable with a lifetime equal to the lifetime of a running system, and which is globally accessible. What exactly constitutes such a definition is a language dependent issue. Besides the inherited attributes, it has the following attributes:

- `scopeQualifier: Qualifier; optional`
  Is a string with a language dependent interpretation, that defines a possible scope of the variable. A null scopeQualifier is allowed, it means that the variable must not be explicitly imported before using it. The scopeQualifier concatenated with the name of the variable must provide a unique name for that variable within the model. Scope qualifiers are not allowed to contain any spaces[5].

- formula for `uniqueName ("::" because a "global" variable has package scope):`

```
if isNull (scopeQualifier(globalVariable)) then
     uniqueName (globalVariable) = name (globalVariable)
   else
     uniqueName (globalVariable) = scopeQualifier (globalVariable)
       + "::" + name (globalVariable)
```

CDIF Example:

```
(GlobalVariable FM23
        (name "TRUE")
        (sourceAnchor #[file "factory.h" start 287 end 291|]#)
        (declaredType "int")
        (declaredClass -NULL-)
        (accessControlQualifier "public")
        (uniqueName "TRUE")
)
```


4.19. ImplicitVariable

ImplicitVariable
scopeQualifier (): Qualifier

Figure 19: ImplicitVariable

An `ImplicitVariable` represents the definition in source code of context dependent reference to a memory location (i.e., 'this' in C++ and Java, 'self' and 'super' in Smalltalk). What exactly constitutes such a definition is a language dependent issue. Besides the inherited attribute, it has the following attributes:

- `scopeQualifier: Qualifier; optional`
  Is a string with a language dependent interpretation, that defines a possible scope of the variable. A null scopeQualifier is allowed, it means that the variable has universal scope. The scopeQualifier concatenated with the name of the variable must provide a unique name for that variable within the model. Scope qualifiers are not allowed to contain any spaces[5].

- formula for `uniqueName:`

```
if isNull (scopeQualifier(implicitVariable)) then
  uniqueName (implicitVariable) = name (implicitVariable)
else
  uniqueName (implicitVariable) =
    scopeQualifier (implicitVariable)
      + "." + name (implicitVariable)
```

4.20. LocalVariable

LocalVariable
belongsTo (): Name

Figure 20: LocalVariable

A `LocalVariable` represents the definition in source code of a variable defined locally to a method. What exactly constitutes such a definition is a language dependent issue. Besides the inherited attributes, it has the following attributes:

- `belongsTo: Name; mandatory`
  Is a name referring to the `BehaviouralEntity` owning the variable. It uses the uniqueName of this entity as a reference.

- formula for `uniqueName:`

```
uniqueName (localVar) = belongsTo (localVar) +
  "." + name (localVar)
```

Example:

```
Class ScrollBar {
        computePosition(int x,int y,int width,int height) {
                int position_;
                . . .
        }
}
```

In CDIF:

```
(LocalVariable FM76
        (name "position_")
        (sourceAnchor #[file "factory.h" start 85 end 89|]#)
        (declaredType "int")
        (declaredClass -NULL-)
        (belongsTo "ScrollBar.computePosition(int,int,int,int)")
        (uniqueName "ScrollBar.computePosition(int,int,int,int).position_
")
)
```

4.21. FormalParameter

FormalParameter
belongsTo (): Name position (): Index isReciever (): Boolean

Figure 21: FormalParameter

A `FormalParameter` represents the definition in source code of a formal parameter. What exactly constitutes such a definition is a language dependent issue. Besides the attributes inherited from `Entity` and `BehaviouralEntity`, it has the following attributes:

- `belongsTo: Name; mandatory`
  Is a name referring to the `BehaviouralEntity` owning the variable. It uses the uniqueName of this entity as a reference.

- `position: Index; mandatory`
  The position of the parameter in the list of parameters.

- `isReciever: Boolean; mandatory; default = 'false'`
  Is a predicate telling whether the parameter plays the role of the receiver. This is required in those cases where the receiver is not passed via an implicit variable, which is quite unusual hence the default value.

- formula for `uniqueName`:

```
uniqueName (formalPar) = belongsTo (formalPar) +
  "." + name (formalPar)
```

Example (`w` is the formal parameter):

```
Window::addWidget(Widget& w) { ...... };
```


In CDIF (`w` is *not* a receiver. This implies the default value `false` for `isReciever` and is therefore the reason that this attribute does not appear in the CDIF representation):

```
(FormalParameterDefinition FM41
        (name "w")
        (declaredType "Widget &")
        (declaredClass "Widget")
        (belongsTo "Window.addWidget(Widget&)")
        (position 1)
        (uniqueName "Window.addWidget(Widget&).w")
)
```

5) Open Questions

5.1. Why not UML?

The unified Modelling Language (UML) [Booc96a] is rapidly becoming the standard modelling language for object-oriented software, even in industry. So, UML is a viable candidate for serving as the data model behind our exchange format. Nevertheless, UML is geared towards an analysis / design language and there exists no accurate and straightforward mapping from source-code to UML. For instance, inheritance like applied in an implementation does not necessarily correspond to generalisation like specified in UML (e.g., in an implementation a Rectangle might be a subclass of Square while a correct generalisation is the other way around). Likewise, attribute definitions do not always correspond with aggregation (e.g., is a Rectangle an aggregation of two instances of Point or is it an aggregation of four integers). Thus choosing UML would violate the requirement that the data model should be readily distillable from source code (see "Requirements Specification" - p.2) and that's the first motivation to rule out UML.

Moreover, extracting an accurate UML model from source code is considered quite important during the model capture phase of the reengineering life cycle (see Figure 1). The FAMOOS project will definitely investigate that topic in further depth, and we do not want to hamper such investigations by choosing a straightforward but inaccurate mapping. That is the second motivation to rule out UML.

Finally, UML does not include internal dependencies such as method invocations and variable accesses. Those dependencies are necessary in the problem detection and reorganisation phases of the reengineering life cycle (see Figure 1). Thus, choosing UML would violate the requirement of being a sufficient basis for reengineering operations (see "Requirements Specification" - p.2).

However, we relied heavily on UML in the terminology and naming conventions applied in our model to become independent of the implementation language. For example, we talk about attributes instead of members (C++) or instance variable (Smalltalk) and we talk about classes instead of types (Ada).

5.2. Why not CORBA/IDL?

CORBA is receiving widespread attention as interoperability standard between different object-oriented implementation languages. The IDL (interface description language) is used to specify the external interface of a software component and there are tools that extract IDL from source code. As such, CORBA/IDL is a viable candidate to serve as our exchange format.

However, CORBA/IDL only describes the interface of a software component, and, like UML, not the internal dependencies such as method invocations and variable accesses. Thus, also CORBA/IDL would violate the requirement of being a sufficient basis for reengineering operations (see "Requirements Specification" - p.2).

5.3. What about Dynamic Information?

Because of polymorphism, not all method invocations can be resolved at compile time. Also, a model based on source code is not ideal for identifying sequences of interactions between objects. Thus, basing the model solely on static information eliminates some interesting facts about a software system and one might consider including run-time information as well.

For the moment we consider the issue too premature to include in an information exchange standard. The technology is available (i.e., Look for C++, method wrappers for Smalltalk) but is certainly not part of the standard tool repertoire. And extracting run-time information generates such a wealth of data that we cannot asses what is important enough to maintain.

5.4. How do you handle hybrid languages (C++, Ada...)?

Some OO languages are extensions of older procedural languages, and as such allow a hybrid programming style. Part of the object-oriented reengineering problem is precisely that programmers did not use object-oriented constructs where it would have been advantageous. For problem detection, it might be worthwhile to include procedural constructs in the model.

For the moment we decided to ignore the issue. We have some ideas on expressing procedural programming constructs as degenerated object-oriented constructs (e.g., define a procedure as a method defined on a dummy class) but no concrete proposal in that direction.

6) References

6.1. FAMOOS Internal References

[DETECTM] FAMOOS Achievement Report DETECTM-A.2.3.2. " Specification of Techniques and Strategies for Problem Detection". Benedikt Schulz, Forschungszentrum Informatik.

[DOCUM] FAMOOS Achievement Report DOCUM-A.2.3.1. " Documentation and Model Capture Method(Grouping)". Oliver Ciupke, Forschungszentrum Informatik.

[EVALCDIF] FAMOOS Achievement Report EVALCDIF "Evaluation of the CDIF Transfer-Format". Thomas Kohler, Daimler-Benz AG.

[REORGOP] FAMOOS Achievement Report REORGOP-A.2.3.3./A.2.3.4. " Specification of Complex Reengineering Operations and Target Structures ". Joachim Weisbrod, Forschungszentrum Informatik.

6.2. External References

[Booc96a] Booch, G., Jacobson, I. and Rumbaugh, J, "The Unified Modelling Language for Object-Oriented Development". See http://www.rational.com/.

[CDIF94a] CDIF Technical Committee, "CDIF Framework for Modelling and Extensibility", Electronic Industries Association, EIA/IS-107, January 1994. See http://www.cdif.org/.

[CDIF94b] CDIF Technical Committee, "CDIF Transfer Format Syntax SYNTAX.1", Electronic Industries Association, EIA/IS-109, January 1994. See http://www.cdif.org/.

[CDIF94c] CDIF Technical Committee, "CDIF Transfer Format Encoding ENCODING.1", Electronic Industries Association, EIA/IS-110, January 1994. See http://www.cdif.org/.

Appendices

A. Clarifications on the CDIF Encoding

To satisfy the requirements for information exchange between tools (see "Requirements Specification" - p.2), we choose the CDIF standard as the basis for transferring information between tools. This choice at least satisfies the "supports industry standards" and the "extensible" requirements. Moreover, CDIF is open with respect to the specific format for a transfer, or —to state it in CDIF terminology— allows for different syntaxes and encodings. By adopting the CDIF syntax SYNTAX.1 with the plain text encoding ENCODING.1 (see [CDIF94b] and [CDIF94c]), we also satisfy the "human readable" and "simple to process" requirements.

CDIF has proven to be a proper solution for our purposes. However, the explicit definition of associations and the lack of multi-valued string attributes leads to verbose transfers that are difficult to read for humans and hinders the merging of information coming from different sources. Also, there are some things we found unclear while reading the CDIF specifications. Therefore, this part of the appendix describes our interpretation of the CDIF standard.

Avoid Explicit Relationships

We avoid explicit relationships for the core model (see Figure 3).This might seem a bit strange at first, but our experiments have shown that heavy use of CDIF relationships compromises the readability of the document a lot. First of all, information gets scattered around in the transfer instead of being nicely encapsulated in the entity it belongs to. And second, CDIF relationships employ meaningless identifiers –unique within the transfer only– instead of references by name. The latter also hinders the combination of information from different sources.

Below is an example of how we encapsulate a "belongsToClass" attribute in Method, instead of defining an explicit "Class.HasMethod.Method" relationship and instantiating it for every Class/Method association. Thus we get ...

```
(Method FM35
        (name "print")
        (belongsToClass "Widget")
        ...
)
```

instead of


```
(Class FM17
        (name "Widget")
        ...
)

...
(Method FM35
        (name "print")
        ...
)

...
(Class.HasMethod.Entity FM56 FM17 FM35)
```

Allow multi-valued String Attributes

To deal with many-to-1 relationships we need multi-valued string attributes. Indeed, we avoid explicit relationships to enhance the readability of a document and to ease combination of information from different sources. However, using a string attribute to encode a relationship (like we did above) only allows for 1-to-many relationships.

CDIF provides IntegerList and PointList in its set of basic data types, thus —in principle— CDIF permits the use of multi-valued attributes. Unfortunately, there is no basic data type that copes with multi-valued strings. Yet, the CDIF "TextValue" data type comes very near, thus in some rare occasions we interpret "TextValue" as a multi-valued text attribute.

In the original CDIF standard, a TextValue denotes a set of characters which is divided into blocks with a maximum of 1024 characters. The beginning of each block is marked by "#[" while the end is marked by "]#". The actual value of the text is the concatenation of the blocks.

To represent a multi-valued string attribute with a TextValue, we interpret each block in a TextValue as a separate string. Also, we require that each one of those strings must append a special delimiter character (which is "|") to its end so that the original multi-valued strings can be retrieved from the concatenated blocks. In the (unlikely) situation that a "|" appears in a string value it should be escaped with "\|". Thus we get ...

```
(Invocation FM35
        (invokedBy "ScrollBar.print()")
        (invokes "print()")
        (candidates     #[Widget.print()|]#,
                        #[MotifWidget.print()|]#,
                        #[SwingWidget.print()|]#)
)
```

instead of (using CDIF relationships):

```
(Invocation FM35
        (invokedBy "ScrollBar.print()")
        (invokes "print()")
)

...

(Candidate FM45
        (value "Widget.print()")
)

(Candidate FM46
        (value "MotifWidget.print()")
)

(Candidate FM47
        (value "SwingWidget.print()")
)

...

(Invocation.HasCandidate.Candidate FM87 FM35 FM45)
(Invocation.HasCandidate.Candidate FM88 FM35 FM46)
(Invocation.HasCandidate.Candidate FM89 FM35 FM47)
```

B. How to extend the model

Considering the "Conception of the Common Exchange Format" (see Figure 2), we see that there are two situations in which the model will be extended. The first corresponds with a language-specific plug-in, while the second corresponds with a tool-specific addition. On the other hand, considering the model itself (see Figure 4 and Figure 5),there are two possible kinds of extensions. One is to add attributes to existing classes, the other is to create new classes.

To ensure that the various tools will be able to deal with all extensions, it is necessary to specify what and how to extend. This is the purpose of the following rules.

1) Language-specific plug-ins are allowed to create new classes (for instance, new kinds of entities and associations) and add new attributes. Tool specific additions are restricted to the addition of new attributes.

2) Additional attributes should **NOT** be introduced via subclasses.

The motivation behind the first rule is that reengineering tools should always be able to work together. A reengineering tool that is dependent of extra classes will complicate co-operation, hence the restriction.

Because the second rule is counter-intuitive, we will ellaborate on the motivation. Indeed, since CDIF offers inheritance, extensions to the model are tempted to create subclasses of existing classes to add new attributes. However, such an approach implies that all tools that process a CDIF transfer must know about the extra subclasses defined in an extension, hence must completely analyse the meta-model part of a CDIF transfer.

As an example consider an extension for a C++ class, where we add an attribute called "friends", which is a multi-valued attribute holding the names of all friend classes and methods

of a certain class. If we define the new attribute as an attribute of "Class", the CDIF transfer will contain a class entity with a potentially unknown attribute. Tools that do not know about this extra attribute may safely ignore it. For instance, a simple querying tool (e.g., grep) will be able extract information out of a transfer (see Figure 22 (a)) without worrying about the extra attribute. However, if we define a new subclass C++Class, which contains the additional attribute, a transfer will contain "C++Class" entities. Tools that do not know about this subclass will break because they do not know the extension and therefore do not recognize the C++Class (see Figure 22 (b)).

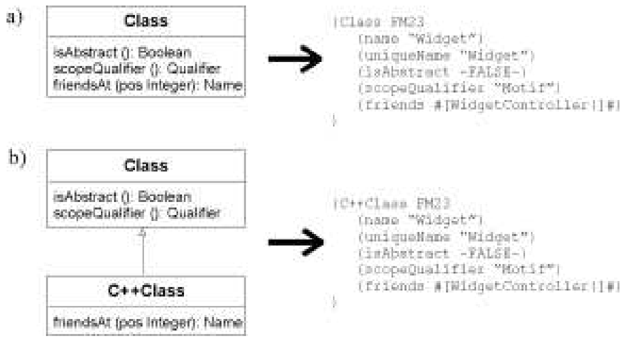


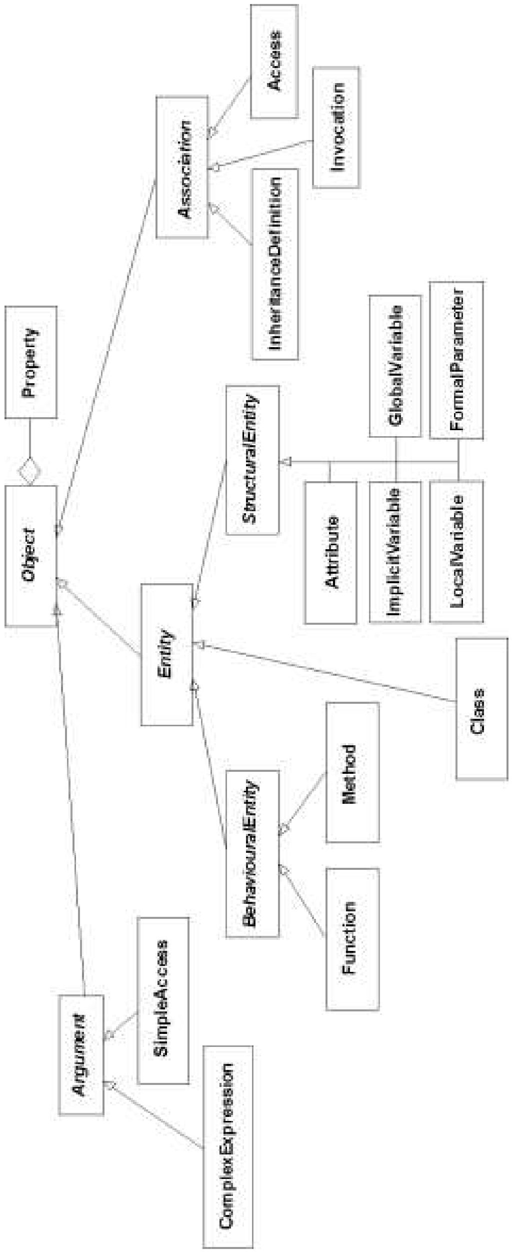
Figure 22: Example of an extension.
(a) without subclassing, correct (b) with subclassing, incorrect.

C. The FAMOOS meta-model in CDIF

The FAMOOS Exchange Model is defined in the subject area FAMOOS. It only uses the Foundation subject area, which is the basic CDIF subject-area that defines an entity-relationship model and is mandatory to use by all models.

For the complete definition of the meta-model in CDIF, check
http://www.iam.unibe.ch/~famoos/InfoExchFormat/

D. The complete FAMOOS Exchange Model



Cover Pages

Achievement A2.4.1

Definition of a Common Exchange Model

1) Identification

Project Id:	Esprit IV #21975 “FAMOOS”
Deliverable Id:	D 2.2 – FINALFHB Final FAMOOS Methodology Handbook
Date for delivery:	31.03.98
Planned date for delivery:	31.03.98
WP(s) contributing to:	2
Author(s):	S. Demeyer, S. Ducasse, T. Richner, M. Rieger, P. Steyaert, S. Tichelaar

2) Abstract

This document defines the exchange model for usage by tool prototypes within the FAMOOS reengineering project. The model is based upon the CDIF standard so that it can be transferred via flat ASCII streams.

3) Keywords

Object-oriented, reengineering, reverse engineering, code repository, FAMOOS.

4) Version History

Ver	Date	Editor(s)	Status & Notes
0.4	17.11.97	S. Demeyer; P. Steyaert	First draft version. Released to all the participants of the Ulm-workshop (21.11.97).
0.5	24.11.97	S. Demeyer	Quick tour of revised model; incorporates feedback generated during workshops at FZI (20.11.97) and Daimler-Benz (21.11.97).
0.6	09.01.98	S. Demeyer	Expanded quick tour into a full specification. Changed original document template for convenient generation of

			HTML. Document is now ready for reviewing and defining language plug-ins.
1.0	30.03.98	S. Demeyer	Final release: • Incorporated feedback given on prior release. • Adapted meta-model to be streamlined with CDIF; removed examples, we first need some tool experience with CDIF. • Introduced the notion of “level of reification”.
1.1alpha	15.06.98	S. Tichelaar	• Adapted the model according to feedback on 1.0 version and experiences using the model in tools: - shortened some names - added Object and Property entity - converged meta-meta-model and meta-model in one model - changed "level of reification" into "level of extraction" – all kinds of small changes • Included CDIF examples and the complete model definition in CDIF as an appendix
1.1	1.07.98	S. Tichelaar, S. Demeyer	• Extended the model to deal with global functions (i.e., introduce BehaviouralEntity and StructuralEntity). • Added appendices about "Clarifications on the CDIF Encoding" and "How to extend the model"

5) Issues for future releases

Some issues couldn't be incorporated in the 1.1 release due to time constraints:

- The model needs basic adaptation to incorporate the notion of packages/modules/... in the core model.

6) Table of Contents

7) List of Figures

8) List of Tables