A Meta-model Semantics for Structural Constraints in ODP computational Language

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Abstract: - The Reference Model for Open Distributed Processing (RM-ODP) provides a framework within which support of distribution, inter-working and portability can be integrated. It defines un object model; architectural concepts and an architecture for the development of ODP systems in terms of five viewpoints. However, RM-ODP is a meta-norm and several ODP standards have to be defined. Indeed the viewpoint languages are abstract in the sense that they define what concepts should be supported not how these concepts should be represented. Using the meta-modeling approach we define in this paper the syntax and a semantics for a fragment of ODP object concepts defined in the foundations part and in the computational viewpoint language. These concepts are suitable for describing and constraining ODP computational viewpoint specifications. This meta-modeling approach could be extended to concepts characterizing dynamic behaviour.

Key-Words: - RM-ODP , Object Concepts, Computational Viewpoint, language, Meta-modeling Syntax & Semantics.

1 Preliminaries.

The rapid growth of distributed processing has led to a need for coordinating framework for the standardization of Open Distributed Processing (ODP). The Reference Model for Open Distributed Processing (RM-ODP) [1-4] provides such a framework. It creates an architecture within which support of distribution, networking and portability can be integrated.
The foundations part [2] contains the definition of the concepts and analytical framework for normalized description of (arbitrary) distributed processing systems. These concepts are grouped in several categories including basic modeling concepts, specifications concepts, organizational concepts, and structuring concepts. The architecture part [3] contains the specifications of the required characteristics that qualify distributed processing as open. It defines a framework comprising

- Five viewpoints, called enterprise, information, computational, engineering and technology which provide a basis for the specification of ODP systems.

- A viewpoint language for each viewpoint, defining concepts and rules for specifying ODP systems from the corresponding viewpoint
- Specifications of the functions required to support ODP systems
- Transparency prescriptions showing how to use the ODP functions to achieve distribution transparency;

.In other words, the three viewpoints do not take into account the distribution and heterogeneity inherent problems. This principle corresponds closely to the concepts of PIP/PSM models in the OMG MDA architecture [5].

However, RM-ODP is a meta-norm [8] and can not be directly applicable. Indeed, for example, the viewpoint languages are abstract in the sense that they define what concepts should be supported, not how these concepts should be represented. It is important to not that, RM-ODP uses the term language in its broadest sense:" a set of terms and rules for the construction of statements from the terms, «and does not propose any notation for supporting the viewpoint languages. In fact, RM-ODP only provides a framework for the definition of new ODP standards. These standards include standards for ODP functions [6-7], standards for modeling and specifying ODP systems; standards for methodology, programming, implementing, and testing ODP systems. Elsewhere the languages Z [9], SDL [10] and LOTOS [11], and Esterelle [12] are used in RM-ODP architectural semantics part [4] for the specification of ODP concepts. Elsewhere, up to now no formal method is likely to be suitable for specifying and verifying every aspect of an ODP system. The inherent characteristics of ODP systems imply the need to integrate different specification languages, and to handle non-behavioral properties of ODP systems.

There had been an amount of research for applying the UML [13] as a syntactic notation to the ODP viewpoints [14-17]. The approach taken is to give a meta-model description for the language ; it is a definition of that language in terms of itself.

This is presented in terms of three views: the abstract syntax, well-formedness rules, and modeling elements semantics. The abstract syntax is expressed using a subset of UML static modeling notations. The well-formedness rules are expressed in OCL [18]. Indeed, we used the meta-modeling approach in our work [19] in order to define the syntax of a sub-language for the ODP QoS-aware enterprise viewpoint specifications. We used OCL for specifying the context constraints of the syntax of the diagrammatical languages defined based on UML.

Elsewhere, a part of UML meta-model itself has a well defined semantics. Hence UML could be adequate for ODP systems which necessitate well formed and unambiguous languages in order to build ODP automatic tools which have to make use of semantic content. In order to give a semantics to a modelling language (which may not be directly executable), there are, essentially two approaches : an axiomatic approach, which states what sentences in the languages ca be derived from other sentences ; and a denotational approach, where expressions are mapped to the « instances » they denote.

A denotational approach [20] would be realised by a) a definition of the form of an instance of every UML language element (e.g. the objects that could be denoted by a class, the links that could be denoted by associations, etc.) and b) a set of rules which determine which instances are and are not denoted by a particular language element.

There are three main steps to a denotational, meta-modelling approach to the semantics approach:
1. Define the meta-model for the language of the model: object template, interface template, action template, type, role
2. Define the met-model for the language of the instances: objects, links, and interfaces,
3. Define the mapping or the meaning function (also within the meta-model) between these two languages.

There are good reasons for adopting a meta-modelling approach for in the context of UML and of ODP systems. The UML meta-models provide a blueprint for the core of any CASE tool. The tools include a consistency checker that makes sure invariants defined on a model do not conflict, a consistency checker between meta-models that makes sure that different system specifications are consistent and do not conflict. Also, tools can be built which generate code from UML meta-models, and these tools can be used to bootstrap themselves every time the meta-model is changed or extended. Furthermore, for testing ODP systems [2-3], the current testing techniques [21], [22] are not widely accepted. However, a new approach for testing, namely agile programming [23], [24] or test first approach [25] is being increasingly adopted. The principle is the integration of the system model and the testing model using UML meta-modeling approach [26].
This approach is based on the executable UML [27]. In this context OCL is used to specify the properties to be tested. OCL also serves to attach constraints to UML meta-models in order to verify the coherence of meta-models and to translate the constraints into code for evaluating them on instance models.
The part of RM-ODP considered in this paper is a subset for describing ODP computational object structure. It consists of modeling and specifying concepts defined in the RM-ODP foundations part and concepts in the computational viewpoint language. We do not consider concepts for describing dynamic behaviour.
For characterizing models, it includes the essentials of class diagrams, and a significant fragment part of the OCL, a precise language based on first order –logic, used for expressing constraints on object structure which cannot be expressed by class diagrams alone. For characterizing instances of models, it includes the language of object diagrams. Because of the role of OCL in ODP information viewpoint specifications, a major component of the meta-model presented is a representation of the concepts underpinning OCL. Thus the UML/OCL meta-model developed here elaborates the conceptual core of the ODP computational viewpoint language for ODP computational specifications. It is not tied to any particular concrete syntax.
Section 2 describes the subset of concepts considered in this paper namely the object model and computational viewpoint. Section 3 describes the meta-model for generic models, object, action, interaction, interface, template, type/subtype, class/subclass, basic class/derived class. Section 4 describes the meta-model for instances of models, which are essentially, object diagrams. Section 5 makes the connection between models and their instances, focusing for the time being, on just roles and template. This introduces the basic form of the semantic approach described here. A conclusion and perspectives end the paper. .

2 The RM-ODP

RM-ODP is a framework for the construction of open distributed systems. It defines a generic object model in the foundations part and an architecture which contains the specifications of the required characteristics that qualify distributed processing as open. The architecture extends and specializes the object concepts of the foundations part.

2.1 The RM-ODP Object Model (Foundations part)

In general, the term object model refers to the collection of concepts used to describe objects in an object-oriented spacification (OMG CORBA object model [2], RM-ODP object model [4]. It corresponds closely too the use of the erm data-model in the relational data model. To avoid misunderstandings, theh RM-ODP defines each of the concepts commonly encountered in objectt oriented models. It underlines a basic object model which is unified in the sense that it has successfully to serve each of the five ODP viewpoints. It defines the basic concepts concerned with existence and activity: the expression of what exists, where it is and what it does. The core concepts defined in the object model are object and action.

An object is the unit of encapsulation : a model of an entity. It is characterized by its behavior and, dually, by its states. Encapsulation means that changes in an object state can occur only as a result of interna actions or interactions.

An action is a concept for modeling something which happens. ODP actions may have a duration and may overlap in time. All actions are associated with at least one object : internal actions are associated with a single object ; interactions are actions asociated with several objects.

Objects have an identity, which means that each object is distinct from any other object. Object identity implies that there exists a reliable way to refer to objects in a model.

Depending on the RM-ODP viewpoint, the emphasis may be placed on the behavior or on the states. When the emphasis is placed on behavior an object is informally said to perform functions and offer services, theses functions are specified in terms of interfaces. It interacts with its environment at its interaction points which are its interfaces. An interface is a subset of the interactions in which an object can participate. In contrast to other object models, an ODP object can have multiple interfaces. Like objects, interfaces can be instantiated.

The other concepts defined in the object model are derived from the concepts of object and action; those are class, template, type, subtype/supertype, subclass/superclass, composition, and behavioral compatibility.

Composition of objects is a combination of two or more objects yielding a new object. An object is behaviorally compatible with a second object with respect to a set of criteria if the first object can replace the second object without the environment being able to notice the difference in the object behavior on the basis of the set of criteria.

A type (of an $<x>) is a predicate characterizing a collection of <x>s. Objects and interfaces can be typed with any predicate, but are commonly typed on the basis of the template of which they are intances. The ODP notion of type is much more general than of most object models. Also ODP allows ODP to have several types, and to dynamically change types.
A class (of an <x>) defines the set of all <x>s satisfying a type. An object class, in the ODP meaning, represents the collection of objects that satisfy a given type. Manyy objectt models do not clearly distinguish between a specification for an object and the set of objects that fit the specification. ODP makes the distinction template and class explicit. The class concept corresponds to the OMG extension concept, the extension of a type is the set of values that satisfy the type at a particular time. A subclass is a subset of a class. A subtype is therefore a predicate that defines a subclass. ODP subtype and subclass hierarchies are thus completely isomorphic.
A <x> template is the specification of the common features of a collection x in a sufficient detail that an x can be instantiated using it.
Types, classes, templates are needed for object, interface, and action.

2. 2 The RM-ODP Computational language

The definition of a language for each viewpoint describes the concepts and rules for specifying ODP systems from the corresponding viewpoint. The object concepts defined in each viewpoint language are specializations of those defined in the foundations part of RM-ODP.

2.2 The RM-ODP computational viewpoint language

A computational specification defines the functional decomposition of an ODP system into objects which interact at interfaces. The basic concepts of the computational language are the computational interface, the computational object, the interaction and the binding object. The binding object is a computational object which supports a binding between a set of other computational objects.
An interaction is either a signal, an operation or a flow.
A signal is an atomic shared action resulting in one-way communication from an initiating object to a responding object.
An operation is an interaction between a client object and a server object.
A flow is an abstraction of a sequence of interactions resulting in a conveyance of information from a producer object to a consumer object.
Like interaction kinds, an interface is either signal, operation or flow.
A signal interface is an interface in which all the interactions are signals.
In an operation interface all the interactions are operations.
All the interactions are flows in a flow interface.
A computational object template comprises a set of computational interface templates which the object can instantiate, a behavior specification and an environment contract specification. The behavior of the object and the environment contract are specified in terms of a set of properties (attributes).

A computational interface template is associated to each kind of interface. It comprises a signal, a stream, or an operation interface signature as appropriate, a behavior specification and an environment contract specification. Like for the object template, the behavior and the environment contract are defined as a set of properties.

2 Syntactic Domain

We define in this section the meta-models for the concepts presented in the previous section. Figure 1 defines the context free syntax for the core object concepts and figure 2 defines the context free syntax for the computational language.
In the following we define context constaints for the defined syntax.

Context m : Model inv :
m.Roles->includesAll(m.Roles.Source ->union(m.Roles.Target)
m.Roles->includesAll(m.ObjectTemplates.Roles)
m.Roles->includesAll(m.Interactiontemplate.roles)
m.Roles->includesAll(m.InterfaceTemplate.roles)
m.InteractionTemplates -> includesAll(m.ObjectTemplates.Interactiontemplates)
m.InteractionTemplates.Types->includesAll(m.Types)
m.ObjectTemplates.InterfaceTemplates->includesAll(m.InterfaceTemplates)
m.ObjectTemplates.InterfaceTemplates->includesAll(m.InterfaceTemplates)
includesAll(m.ObjectTemplates.Interactiontemplates)
m.Types->includesAll(m.InteractionTemplates.Types-
>union(m.InterfaceTemplates.Types)- >union(m.InteractionTemplate.Target)

Context i : Interaction template inv :
r.role.inverse = r.Interactions.Roles.Source .inverse
and r.role.source = r.Interactions.Roles.Source .source
and r.role.source.inverse = r.Interactions.Roles.Source .inverse

Context o : Object Template inv :
cot is not parent of or child of itself
not (cot.parents ->includes(cot) or cot.children->includes(cot))

3 Semantics Domain

The semantics of a UML model is given by constraining the relationship between a model and possible instances of that model. That is, constraining the relationship between expressions of the UML abstract syntax for models and expressions of the UML abstract syntax for instances.
We define a model to be the ODP computational viewpoint specification. That is, a set of computational objects which interact with each other at their interfaces possibly via a binder object. The figure 3 defines the semantic domain.

A system can only be an instance of a single system model, because here models are self contained and disjoint from other models (excepting the special case where a model is behaving as a namespace for in invariant).

Objects are instances of one ore more object templates, they may be of one or more types. With no further constraints, it is possible for an object to change de templates of which it is an instance ; thus this met-model supports dynamic types

There is one well-formedness rule for instances (the left-hand side of the diagram), which is given bellow :

Context s : system inv :

The source and target objects of s'slinks are objects in s
s.objects->includesAll(s.links.source -> union(s.links.target)

links between two objects are unique per role
&s.links->forAll(l| s.links->select(l'|l'.source=l.source&l'.target=l.target&l'.of=l.of)=l)

Other invariants are required constraining the relationships between models and instances. These constitute the semantics and are the subject of the next section.

4 Semantics function: the basics

The semantics for the UML-based language defined focuses on the relationship between a system model and its possible instances (systems). The constraints are relatively simple, ignoring invariants for the time being , but they demonstrate the general principle.
Firstly there are two constraints relating to objects and binders, respectively.
The first shows how inheritance relationships can force an object to be of many classes.
Context o : object inv :
The templates of o must be a signe template and all the parents of that template
o.of->exists(t | o.of=t->union(t.parents))

The second ensures that a binder connects objects of templates as dictated by its role.
Context b : binder inv :
Objects which are the source/target of binder are of templates which are at the source/target of the corresponding roles
(b.of.source) -> intersection (l.source.of) -> notEmpty
and (l.of.target)->intersection (l.target.of) -> notEmpty
Secondly, there are four constraints which ensure that a model instance is a valid instance of the model it is claimed to be an instance of.

The first and second ensure that objects and interfaces are associated with templates known in the model.

Context s : system inv :

The model, that s is an instance of, includes all object templates that s.objects are instances of

s.of.ObjectTemplates->includesAll(s.Objects.of)

The model, that s is an instance of, includes all interface templates that s.interfaces are instances of

s.of.InterfaceTemplates->includesAll(s.Interfaces.of)

The third ensure that binders are associated with roles known in the model.

Context s : system inv :

The model, that s is an instance of, includes all the roles that s.binder are instances of

s.of.roles ->includesAll(s.binders.of)

The fourth constraint ensurs that within the system cardinality constraints on roles are observed.

Context s : system inv :

The binders of s respect cardinality constraints for their corrseponding role

```
s.binders.of -> forAll( r | let binders_in_s be
        r.instances ->intersect ( s.binders )  in
        ( r.upperBound -> notEmpty  implies binders_in_s ->size  <= r.upperBound )
         and binders_in_s->size >= r.upperbound)
```

The fifth ensures that reverse binders are in place for roles with inverses.

Context s : system inv :

if a binder is of a role with an inverse, then there is a corresponding reverse binder

```
 s.binders->forAll (l | l.of.role.inverse ->notEmpty implies s.binders ->select ( l' |
l'.source=l.target & l'.target=l.source & l'.of = l..of.inverse)->size=1
```

4 Conclusion

The Reference Model for Open Distributed Processing (RM-ODP) provides a framework within which support of distribution, inter-working and portability can be integrated. However, RM-ODP is a meta-norm and several ODP standards have to be defined. Indeed the viewpoint languages are abstract in the sense that they define what concepts should be supported not how these concepts should be represented. Using the meta-modeling approach we define in this paper the syntax and a semantics for a fragment of ODP object concepts defined in the foundations part and in the computational viewpoint language. These concepts are suitable for describing and constraining ODP computational viewpoint specifications. This meta-modeling approach could be extended to concepts characterizing dynamic behaviour.

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