Computer Science
Technical Report

Colorado State University

An Activity Theory Language: USE Implementation

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January 15, 2013

Technical Report CS-13-101

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Introduction

This document contains the meta-model we have defined for an Activity Theory language and the USE tool implementation we have created for it, along with results of testing it in the USE environment.

The purpose of the AT language is for requirements elicitation. A user will create Activity Theory System Diagrams (ASDs) from stakeholder input. The elements and their relations as defined in this document can be used to determine whether such an ASD is well-formed. The relations in particular can also be used to decide where further input is needed from stakeholders to resolve vagueness or contradictory information. It is also our intention in the future to provide enough structure to some of the elements such as Rules that some simple natural language processing can be used to identify potential overlap/contradictions that may need additional stakeholder dialog.

ASDs can be decomposed and refined, as well as networked together to show how elements produced by one activity can provide elements used by other activities. Decomposition and network relations are also included in the meta-model. Definitions and constraints are presented in OCL and in natural language alongside related portions of the meta-model.

A specific example ASD is used to demonstrate elements and relations. This is the *Survey Premises* ASD from the vector surveillance system developed in Mexico. It is an ASD at a rather low level of abstraction, so its scope is quite limited.

Acknowledgements

Thanks to Wuliang Sun, who created the first version of an ECORE model and a USE tool class model with OCL constraints from the first version of the meta-model described in this document. Thanks also to Martin Gogolla, leader of the group who developed the USE tool, and Gunter Mussbacher, developer of AoURN, for their consultations regarding modeling composite structures in the USE meta-model. Working with the USE tool has provided additional insight into required constraints, which have been incorporated into the USE description.

Activity Theory

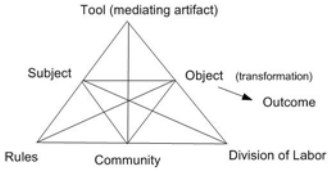


Figure 1. Activity System Diagram (ASD).

AT defines human activity as a system of multiple elements and their mediating relations. The activity system as a whole evolves over time in response to contradictions within and between its elements.

Engeström introduced a diagram format to model activity systems (Fig. 1) [Engeström]. We call such diagrams Activity System Diagrams, or ASDs. Briefly, the *object* of a human activity is transformed into the *outcome* by the *subject*, using the mediating *tool*. The object can be physical or conceptual, as can the tool. The subject can be an individual or a group. The *community* is anyone sharing the same object. *Subject* relations to the community are mediated by *rules*, which are implicit and explicit norms and conventions. The object and community relations are mediated by the *division of labor (DoL)*, which determines how the task of achieving the object is distributed. Identifying the mediating rules and DoL helps make explicit the often implicit goals and actions of stakeholders, and can help predict their reactions during activity execution.

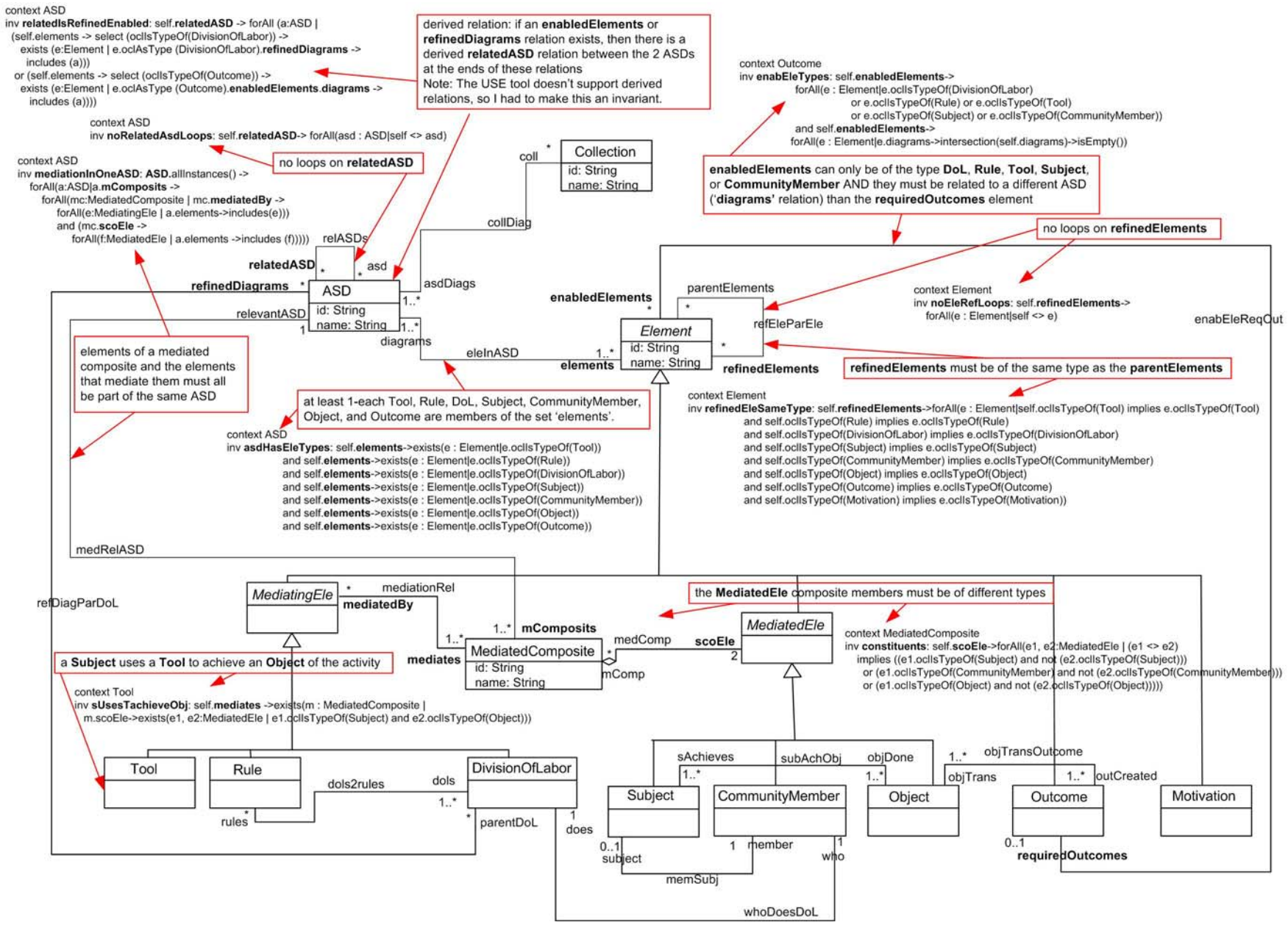
Elements of an AT Model, Decomposition, and Networked Systems

Figure 2 shows the AT language meta-model we have developed, which includes AT elements and the relationships between them. Several constraints are shown (written as English text), outlined in red, with red arrows pointing to the actual OCL in the USE model, and to the location in the meta-model where they apply.

Notes.

- We have left out the concept of an *activity*. It is possible that an *activity* is similar to the abstract *Element* – it is an abstract concept whose realization is an ASD.
- Not shown are the operations that will be allowed on an ASD and its elements. In particular an ASD should have the ability to be manipulated to be printed, scaled, persisted, etc. These operations will not be part of the meta-model, but need to be specified to be part of any toolset.
- Hierarchical refinement, or decomposition, of an **activity** is shown through the *refDiagParDoL* relation between *DivisionOfLabor* and *ASD*.
- Hierarchical refinement, or decomposition, of an **Element** is shown through the *refEleParEle* relation between *Element* and itself. This decomposition is currently constrained to result in elements of the same type.
- Networked ASDs are shown through the *enabEleReqOut* relation between *Outcome* and *Element*. The type of *Element* is restricted to *Rule*, *Tool*, *Subject*, or *CommunityMember*.
- DoL items are related to a community member who accomplishes them (*whoDoesDoL* relation). DoL items may also be related to particular Rules (*dols2rules* relation).
- Activity Theory relies on mediation as a major concept. An activity consists of elements that are mediated by other elements. While mediation is discussed in more detail later in this report, we note that certain elements are always considered as mediating elements while other are mediated. This has led us to add abstract classes for each type of element along with OCL constraints relevant to the AT concept of mediation.
- Examples are taken from the vector surveillance portion of a data capture and interpretation system designed to help in the control of Dengue virus and disease in Merida, Yucatan, Mexico. This project was a joint project between Colorado State University, Microbiology, Immunology, and Pathology department and two universities in Mexico [Eisen]. CSU's Computer Science department participated in a project to develop a cell phone application to be taken into the field for data entry regarding potential breeding sites of the Dengue vector, a mosquito [Lozano]. The cell phone application allows field agents to enter data regarding the number and type of potential breeding sites into the cell phone, from where it is automatically uploaded to a central database.

Figure 2. AT language meta-model



Hierarchical Refinement: Decomposition

We note that a division of labor item can be an activity itself, as shown through the *refDiagParDol* relation. When this is done, the applicable rules need to be preserved or refined in the decomposed activity. Thus there is an additional relation we need to establish between rules and the DoL they affect. This is indicated by the *dols2rules* relation. Each such rule must be included in a complete decomposition either as is, or in a refined version. Note that a single DoL may be refined into multiple ASDs. The constraint would be that all rules associated with the original DoL must either remain as they are or be refined in the set of diagrams refined from the initial DoL.

However, there is an issue here, since a modeler may choose to only refine one portion of a DoL, and therefore some of the rules may not be applicable. An example of such a situation is the DoL for a Field Agent to perform Vector Surveillance. There could be two sub-tasks to this DoL – maybe something like capturing mosquitos, and counting containers. These two tasks could both be refined into separate ASDs, but maybe not. There could be rules that apply to one or the other in the "parent" ASD, which would not be included in a refinement of one portion of the DoL.

While we have not added any constraints around this situation, we need to keep it in mind for future revision.

Mediation

A basic premise of Activity Theory is that all human activity is mediated. In the Engeström diagram (Fig. 1), the mediat**ing** elements are Tool, Rule, and Division of Labor. The elements that are mediat**ed** are Subject, Community, and Object. We have constrained diagrams to ensure that for every mediating element, there is an associated mediated composite: two mediated elements; for example, subject and community are mediated by rules, as are subject and object, and community and object. Similar relations exist for these mediated composites and the other mediating elements.

The subject relation to the community is mediated by rules, which are implicit and explicit norms and conventions. The object and community relation is mediated by the division of labor, which tells how the task of achieving the object is divided up across the community. Division of labor also has a vertical component describing the power structure of the community as it relates to the activity object.

Thus, the abstract classes *MediatingEle* and *MediatedEle* are included in the meta-model to partition the Elements, and a *MediatedComposite* added to group the mediated elements. The *MediatedComposite* is an aggregation, not a composition since the mediated elements may exist independent of a composite. For example, a particular subject no doubt exits in multiple ASDs, and may participate as half of a mediated composite in different ways depending on the ASD.

Constraints

1. Element is specialized to MediatingEle and MediatedEle, in addition to Outcome and Motivation specializations. Tool, Rule, and DivisionOfLabor are specializations of MediatingEle and Subject, CommunityMember, and Object are specializations of MediatedEle.

2. MediatedComposite is an aggregation of 2 MediatedEle. The OCL constraint **constituents** states that these two elements must be of different specialization types (e.g. subject and object, not subject and subject).

3. A MediatedComposite has a relation with a MediatingEle, called mediationRel. There may be combinations of MediatedComposites that have no relation with a particular MediatingEle, but each MediatingEle must have a relation with one or more MediatedComposites. This constraint is enforced

with multiplicities. We added this constraint to ensure that mediating elements which do not mediate anything in the ASD are not included in the ASD.

4. A Subject uses a Tool to achieve an Object of the activity. This means there must be at least one MediatedComposite consisting of a subject and object, and it has to be related to a tool. The OCL constraint **sUsesTachieveObj** states this. We added this constraint since #3 would only ensure that a tool was related to one mediated composite, which may not include a subject and object.

5. The two elements of a MediatedComposite and the MediatingElement related to it must all be associated with the same ASD. The relation medRelASD partially enforces this constraint, through multiplicities that each MediatedComposite must be associated with one ASD, and every ASD has to have at least one MediatedComposite. The rest of the constraint is enforced through the OCL **mediationInOneASD** constraint, which states that all three elements involved must belong to the set of elements associated with the ASD through the eleInASD relation.

Subject-Tool-Object Mediation

See Constraint #4 above.

This relation is a critical relation because it is the basis of the entire activity. The object is the object of the activity. It is transformed into the outcome by the subject, using the mediating tool. The object can be physical or conceptual, as can the tool. The subject can be an individual or a group.

The associated constraint is shown in Figure1 in the Tool context: "a **Subject** uses a **Tool** to achieve an **Object** of the activity". This constraint is in addition to the constraint that each mediating element must have at least one mediated composite related to it. Thus, a tool can be related to a community member and object or a subject and community member, but is MUST also be related to a subject and object.

Community-Object Relations

There is another relation between the subjects and community members that provides constraints on these elements.

The community is everyone who "shares" the object. Thus we could add a shares relation between *CommunityMember* and *Object* with the constraint that all *CommunityMember* objects in an ASD have this relation to 1 or more of the *Object* objects in the ASD. This relation is not included in the v5 meta-model, and it isn't clear that we need it.

It is possible that the community should include everyone who is responsible for completing a DoL item. Given that DoL items are not specified as including "people" there is no way to add a constraint in this version of the meta-model. It is also not clear that it is needed; it is possible that there could be cases where a DoL item is not performed by someone who is a member of the community.

Mediation Relation Example ASD

We discuss examples of mediation relations in the context of the Survey Premises ASD, which is shown in Figure 3.

Dengue is a virus that is transmitted by mosquitos. It is endemic to the tropics and sub-tropics, and due to warmer weather and global travel cases are being seen all over the world. The virus causes Dengue diseases, which are manifested in several forms. An infected person may exhibit anything from no symptoms, flu-like symptoms related to Dengue Fever, up to the potentially fatal Dengue Hemorrhagic

Fever. Since the disease is caused by a virus there is no cure. Additionally, there are four different types of the virus, and survival of one type does not imply immunity to any of the other types. The mosquito is *Aedes aegypti*, the same mosquito that carries yellow fever. This mosquito is fond of relatively clean water, and is often found near humans. Anything that contains clean water and is uncovered is a potential breeding site for this mosquito.

The best prevention of Dengue has been found to be the removal of breeding or potential breeding sites. Thus, the major component of Dengue control in the city of Merida is looking for potential breeding sites and removing them. This task is performed by field agents who follow a list of premises to check. The task list is created by coordinators, who take into account localities where people with confirmed cases of the disease live, as well as locations with previously high numbers of potential breeding sites, or where larvae, pupae, or adult mosquitos were found. The World Health Organization (WHO) has established allowable densities of breeding sites, larvae, pupae, and adults, and if an area goes above these levels then additional activities must be undertaken. A common response is to spray for adults, or apply larvacide, or make people remove breeding sites from their homes. Potential breeding sites can be old tires where rain collects, or other uncovered containers a resident may have for the purpose of collecting or storing water. A common practice in Merida is to engage the municipal garbage collection agency to make special trips to affected neighborhoods in order to collect the items that may act as breeding sites.

Historically, field agents have used a paper form to collect data from premises regarding the number and type of containers they find, whether they have water in them, and whether they also have any larvae, pupae, or adults. The cell phone application developed at CSU automated some of this information: a list of premises to survey is downloaded to each field agent's cell phone, where it is updated as the field agent works. The application allows the field agent to input all the data about containers, and then uploads it to a central database when the agent is finished. One major constraint on the entire surveillance activity is that field agents must obtain permission before they can survey a residence. If the homeowner or tenant is not at home or does not give permission, then data for that locality cannot be obtained.

The activity we use as an example is that of actually surveying a premise. This activity has a network relationship to an activity performed by coordinators to assign surveillance tasks to the field agents. The list that results from this second activity is a tool used by field agents in the survey premise activity.

The Survey Premises ASD shown in Figure 3 is based on the cell phone application [Lozano]. It relies on a network of ASD to provide tools – in particular a coordinator task that creates field agent premises surveillance lists. The outcome of the coordinator activity, *Assign Surveillance Tasks to Personnel*, is used as a tool in the survey premises activity. However, the list is not necessarily static; it can be changed while the survey premises activity is being performed. Therefore there is also a division of labor listed in the survey premise activity noting that the coordinator may modify the list.

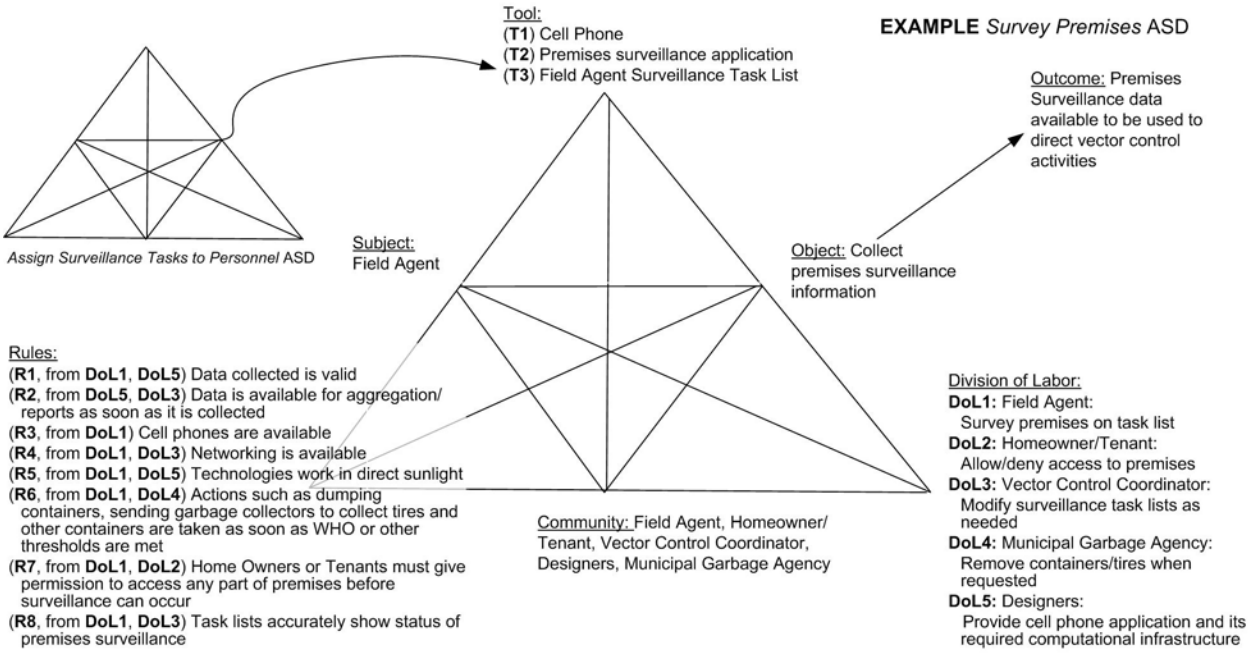


Figure 3. Survey Premises ASD

Mediation Relations

There are three types of mediation relations, shown by the three lines coming into each role in the Engeström diagram.

For each mediating element (Rule, Tool, DoL) in the following figures, the upper left corner of the figure shows a complete ASD with the element types labeled, to be used as a reference. An outlined text box showing all possible relations suggested by the relevant portion of the triangle diagram is immediately to its right. Below these two items is the portion of the meta-model that shows the relation, and the constraints we have identified. On the right side of the figure is the relevant portion of the *Survey Premises* ASD, and under it is a table that shows the specific relation information for each item. For example, Figure 4 shows the mediation relations provided by rules; between subject, community, and object. The table shows that for the example ASD, Rule 1 (*Data collected is valid*), provides mediation between a subject and object, and the subject is a *Field Agent*, and the Object is to *Collect surveillance information*.

Determining Relations Mediated by Rules

Each rule should be related to at least 1 division of labor item. The idea here is that if a rule is not related to any task associated with the activity, then it doesn't belong in the activity, but rather in some other activity. The problem here is to identify all subjects, objects, and community members that are mediated by the rule. The following questions can help:

Who cares about the rule being followed? Why (i.e. what DoL is impacted by this rule)? What DoL is directly affected by this rule? Who is affected by it? Rules ONLY mediate between Subject and Object, Community and Object, and Subject and Community.

Determining Relations Mediated by Division of Labor

Figure 5 shows mediation by Division of Labor. As in previous diagrams of the meta-model, constraints regarding these relations are shown in English in a red box, with red arrows to the OCL statements and to the portion of the diagram that is affected.

Each DoL item mediates between the associated community member and the object. Also, each DoL item mediates between the subject and the community member.

As in Figure 1, constraints regarding these relations are shown in English in a red box, with red arrows to the OCL statements and to the portion of the diagram that is affected.

Determining Relations Mediated by Tools

Figure 6 shows mediation by Tools. As in previous diagrams of the meta-model, constraints regarding these relations are shown in English in a red box, with red arrows to the OCL statements and to the portion of the diagram that is affected.

All tools mediate between the subject who uses them and an object. Some tools mediate between community members and the object, as well as between community members and the subject.

Analysis

We are able to analyze models created with the AT language for structural correctness based on the structure defined in the meta-model and the structural OCL constraints (e.g. at least 1 of each type of element except motivation…).

In addition, the property relating tools, rules, and DoLs allows us to analyze an ASD for at least one component of completeness, and over-specification. The property is tht a tool, rule or DoL item explicitly mediates some relation, AND it is required to be used/followed/executed in order for the subject(s) to be able to successfully achieve the activity object(s). Therefore the set of all *Rules* and the set of all *DivisionOfLabor* items and the set of all *Tools* are necessary and sufficient for a Subject to achieve an Object.

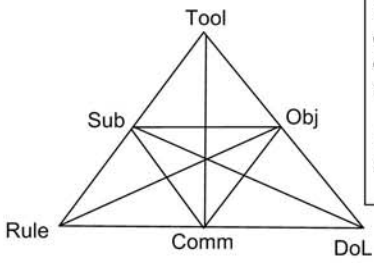
If we identify a rule, DOL, or tool that isn't mandatory for the subject to be able to achieve the object then it doesn't belong in the ASD. Similarly, during requirements elicitation, if stakeholders identify a rule, DoL, or tool that isn't in an ASD and it affects whether the subject can achieve the object then it should be added to the ASD.

In addition to structural analysis, Activity Theory contains addresses various forms of contradictions that can be seen within and across activities. According to the theory, these contradictions lead to evolution of the activity. While we are not yet able to automate discovering such contradictions, they may still become evident as a part of the elicitation process and construction of ASD models.

An example of an intra-element contradiction is between "(R6) Actions such as dumping containers, sending garbage collectors to collect tires and other containers are taken as soon as WHO or other thresholds are met" and "(R7) Home Owners/Tenants must give permission to access any part of premises before surveillance can occur." R7 deals with property rights, which are in dispute if garbage collection automatically occurs even if home owners/tenants are opposed to throwing away their property. An example of inter-element contradiction occurs between R7 and the object of the activity: "Collect surveillance information." Clearly if a homeowner does not grant permission then surveillance information cannot be collected.

Our future work includes specification notations and analysis to automate identification of various kinds of contradictions in ASDs.

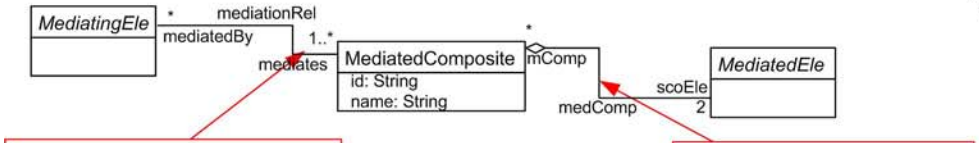
Figure 4. Mediation by Rules



Every 2 elements connected by a line through a 3rd can have a relation that is mediated by the 3rd element. E.g. Subject and Community have relationships mediated by Rules:

1) S-C mediated by R, S-O mediated by R, C-O mediated by R

Case 1) S-C mediated by R, S-O mediated by R, C-O mediated by R



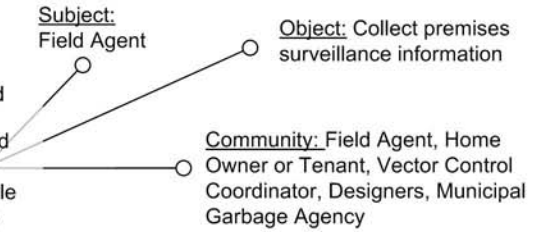
Constraints:

Every rule has to be associated with at least one of these "composite structures".

the **MediatedEle** composite members must be of different types

```
context MediatedComposite
inv constituents: self.scoEle->forAll(e1, e2 : MediatedEle | (e1 <> e2) implies
      (e1.oclIsTypeOf(Subject) and not ( e2.oclIsTypeOf(Subject)))
       or (e1.oclIsTypeOf(CommunityMember) and not ( e2.oclIsTypeOf(CommunityMember)))
       or (e1.oclIsTypeOf(Object) and not ( e2.oclIsTypeOf(Object)))))
```

EXAMPLE from *Survey Premises* ASD (various paper drafts):

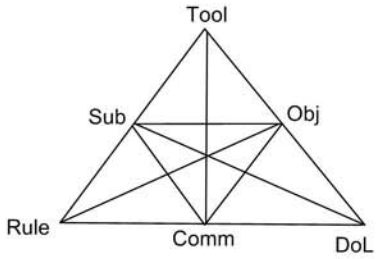


Rules:

(**R1**, from **DoL1**, **DoL5**) Data collected is valid
(**R2**, from **DoL5**, **DoL3**) Data is available for aggregation/reports as soon as it is collected
(**R3**, from **DoL1**) Cell phones are available
(**R4**, from **DoL1**, **DoL3**) Networking is available
(**R5**, from **DoL1**, **DoL5**) Technologies work in direct sunlight
(**R6**, from **DoL1**, **DoL4**) Actions such as dumping containers, sending garbage collectors to collect tires and other containers are taken as soon as WHO or other thresholds are met
(**R7**, from **DoL1**, **DoL2**) Home Owners or Tenants must give permission to access any part of premises before surveillance can occur
(**R8**, from **DoL1**, **DoL3**) Task lists accurately show status of premises surveillance

Rule	Relation Type	Subject	Community Member	Object
R1	S-O to R	Field Agent		Collect Surveillance information
R1	C-O to R		Home Owner/Tenant (HOT)	Collect Surveillance information
R1	C-O to R		Designers	Collect Surveillance information
R1	C-S to R	Field Agent	Vector Control Coordinator (VCC)	
R2	C-O to R		VCC	Collect Surveillance information
R2	C-O to R		Designers	Collect Surveillance information
R3	S-O to R	Field Agent		Collect Surveillance information
R4	S-O to R	Field Agent		Collect Surveillance information
R4	C-O to R		Designers	Collect Surveillance information
R5	S-O to R	Field Agent		Collect Surveillance information
R5	C-O to R	Designers		Collect Surveillance information
R6	S-O to R	Field Agent		Collect Surveillance information
R6	C-O to R		VCC	Collect Surveillance information
R6	C-O to R		Designers	Collect Surveillance information
R6	C-S to R	Field Agent	HOT	
R7	C-S to R	Field Agent	HOT	
R8	S-O to R	Field Agent		Collect Surveillance information
R8	C-O to R		HOT	Collect Surveillance information
R8	C-O to R		Designers	Collect Surveillance information
R8	C-S to R	Field Agent	VCC	

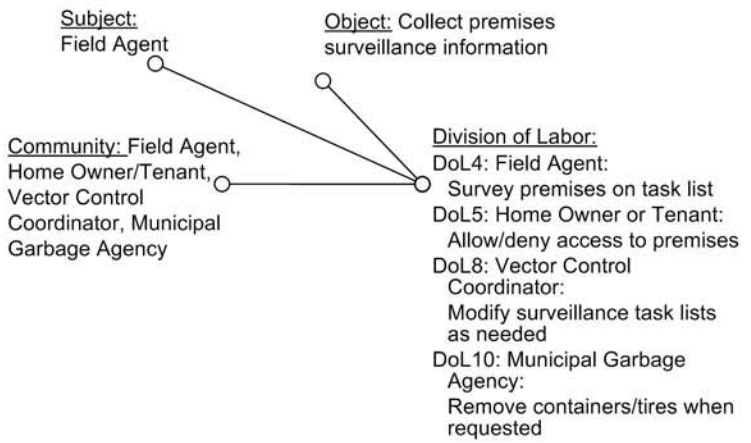
Figure 5. Mediation by Division of Labor



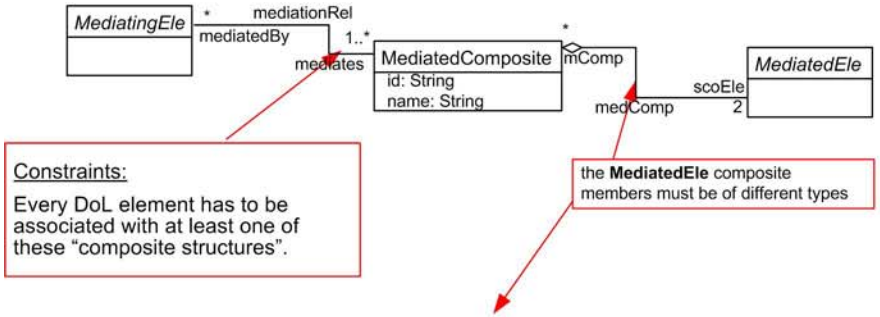
Every 2 elements connected by a line through a 3rd can have a relation that is mediated by the 3rd element. E.g. Subject and Community have relationships mediated by DivisionOfLabor elements:

2) S-O mediated by DoL, C-O mediated by DoL, S-C mediated by DoL

EXAMPLE from *Survey Premises* ASD (various paper drafts):



Case 2) S-O mediated by DoL, C-O mediated by DoL, S-C mediated by DoL

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inv constituents: self.scoEle->forAll(e1, e2 : MediatedEle | (e1 <> e2) implies
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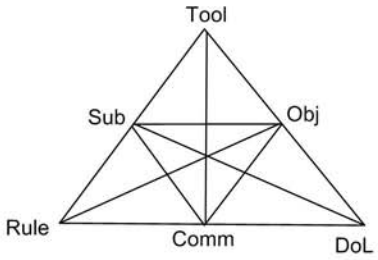
       or (e1.oclIsTypeOf(CommunityMember) and not ( e2.oclIsTypeOf(CommunityMember)))
       or (e1.oclIsTypeOf(Object) and not ( e2.oclIsTypeOf(Object)))))
```

DoL	Relation Type	Subject	Community Member	Object
DoL1	S-O to DoL	Field Agent		Collect Surveillance information
DoL2	C-O to DoL		Home Owner/Tenant (HOT)	Collect Surveillance information
DoL2	C-S to DoL	Field Agent	HOT	Collect Surveillance information
DoL3	C-O to DoL		Vector Control Coordinator (VCC)	Collect Surveillance information
DoL3	C-S to DoL	Field Agent	VCC	Collect Surveillance information
DoL4	C-O to DoL		Municipal Garbage Agency (MGA)	Collect Surveillance information
DoL4	C-S to DoL	Field Agent	MGA	Collect Surveillance information
DoL5	C-O to DoL		Designers	Collect Surveillance information
DoL5	C-S to DoL	Field Agent	Designers	Collect Surveillance information

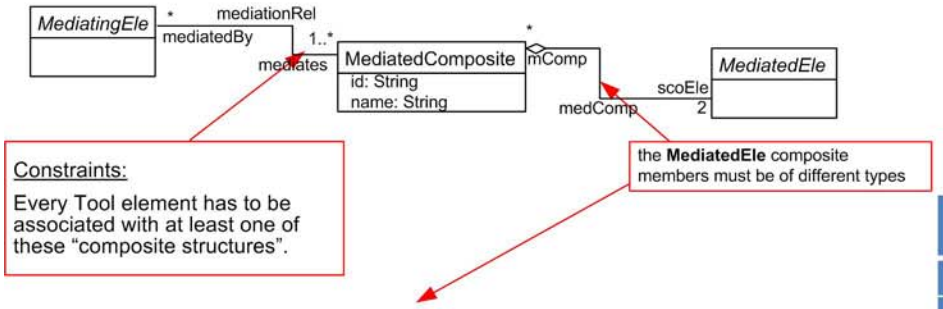
Figure 6. Mediation by Tools



Every 2 elements connected by a line through a 3rd can have a relation that is mediated by the 3rd element. E.g. Subject and Community have relationships mediated by Tools:

3) S-O mediated by T, C-O mediated by T, S-C mediated by T

Case 3) S-O mediated by T, C-O mediated by T, S-C mediated by T



Constraints:

Every Tool element has to be associated with at least one of these "composite structures".

the **MediatedEle** composite members must be of different types

```
context MediatedComposite
inv constituents: self.scoEle->forAll(e1, e2 : MediatedEle | (e1 <> e2) implies
      (e1.oclIsTypeOf(Subject) and not ( e2.oclIsTypeOf(Subject)))
       or (e1.oclIsTypeOf(CommunityMember) and not ( e2.oclIsTypeOf(CommunityMember)))
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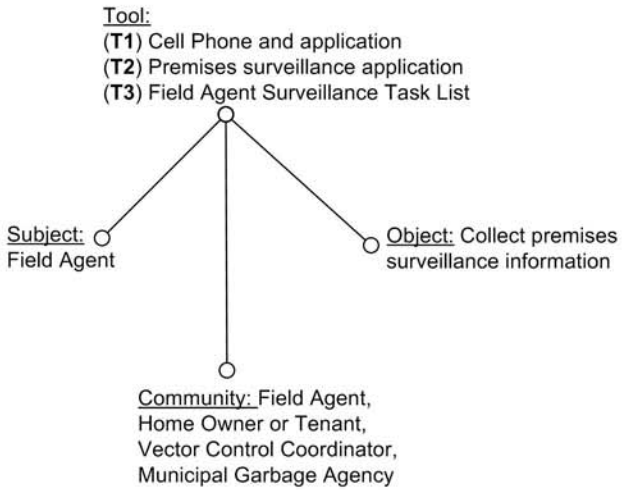

Tool	Relation Type	Subject	Community Member	Object
T1	S-O to T	Field Agent		Collect Surveillance information
T2	S-O to T	Field Agent		Collect Surveillance information
T2	C-O to T		Home Owner/Tenant (HOT)	Collect Surveillance information
T2	C-O to T		Designers	Collect Surveillance information
T3	S-O to T	Field Agent		Collect Surveillance information
T3	C-O to T		Vector Control Coordinator (VCC)	Collect Surveillance information
T3	C-S to T	Field Agent	VCC	Collect Surveillance information

USE Tool Model

The meta-model shown in Fig. 1 has been implemented in the USE tool [USE]. The USE class model representing the AT meta-model is shown in Figure 7. The results of evaluating the OCL constraints in the meta-model are also shown in Figure 7. These constraints all evaluate to *True* which indicates that there are no inconsistencies in the meta-model structural or OCL constraints.

We have also successfullly created USE instances of ASDs, and defined relations among them, including both hierarchical decomposition and network relations. The ability of USE to check structural constraints and OCL constraints at any point in the creation of these ASDs helped enormously since an ASD can become fairly complex quickly.

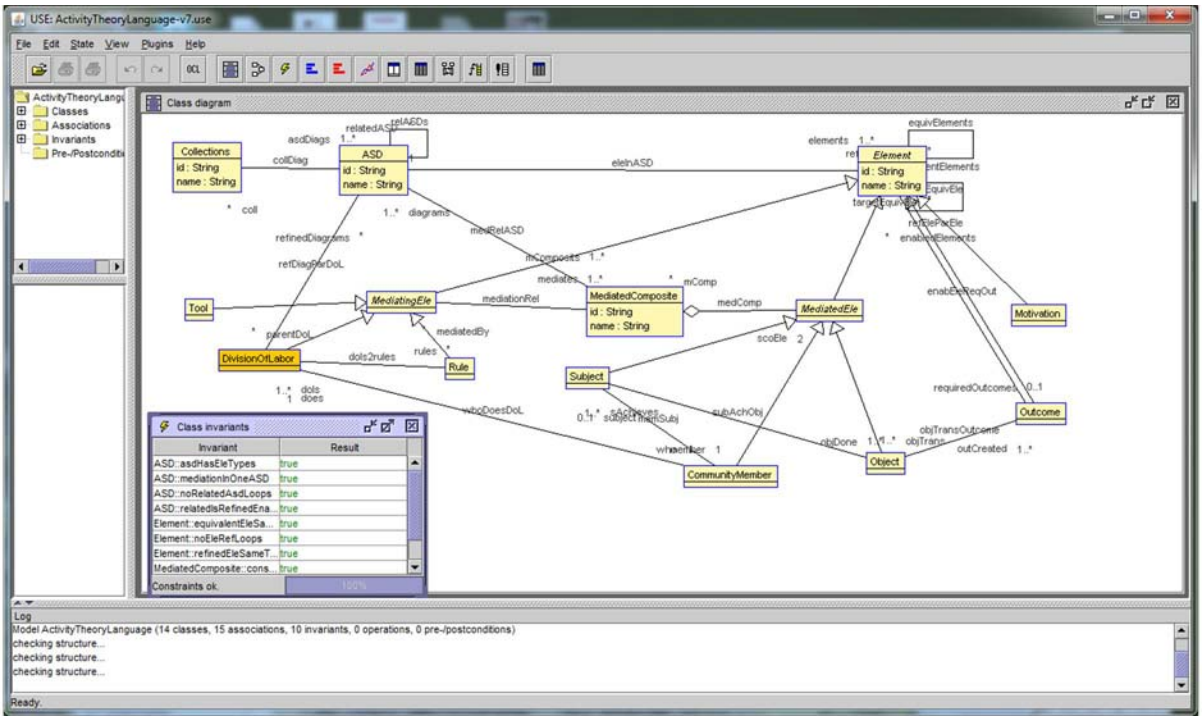

Figure 7. AT language USE model and results of OCL constraint evaluation

The full USE textual model is given in Listing 1, below. The first part of the model (through line 160) that defines the classes and associations, is shown in 2-column format. The remainder of the model, that defines the constraints, is shown in single-column format.

```
1 model ActivityTheoryLanguage
2 – AT Language V5 USE Model
3
4 class Tool < MediatingEle
5 attributes
6 operations
7 end
8
9 class Rule < MediatingEle
10 attributes
11 operations
12 end
13
14 class DivisionOfLabor < MediatingEle
15 attributes
16 operations
17 end
18
19 class Subject < MediatedEle
20 attributes
21 operations
22 end
23
24 class CommunityMember < MediatedEle
25 attributes
26 operations
27 end
28
29 class Object < MediatedEle
30 attributes
```

```
31 operations
32 end
33
34 class Outcome < Element
35 attributes
36 operations
37 end
38
39 class Motivation < Element
40 attributes
41 operations
42 end
43
44 abstract class MediatingEle < Element
45 attributes
46 operations
47 end
48
49 abstract class MediatedEle < Element
50 attributes
51 operations
52 end
53
54 abstract class Element
55 attributes
56 id : String
57 name : String
58 operations
59 end
60
61 class MediatedComposite
62 attributes
63 id : String
64 name : String
65 operations
66 end
67
68 class ASD
69 attributes
70 id : String
71 name : String
72 operations
73 end
74
75 class Collections
76 attributes
77 id : String
78 name : String
79 operations
80 end
81
82 aggregation medComp between
83 MediatedComposite[1] role mComp
84 MediatedEle[2] role scoEle
85 end
86
87 association mediationRel between
88 MediatingEle[0..*] role mediatedBy
89 MediatedComposite[1..*] role mediates
90 end
91
92 association dols2rules between
93 DivisionOfLabor[1..*] role dols
94 Rule[0..*] role rules
95 end
96
97 association refDiagParDoL between
98 ASD[0..*] role refinedDiagrams
99 DivisionOfLabor[0..*] role parentDoL
100 end
101
102 association whoDoesDoL between
103 DivisionOfLabor[1..1] role does
104 CommunityMember[1..1] role who
105 end
106
107 association memSubj between
108 CommunityMember[1..1] role member
109 Subject[0..1] role subject
110 end
111
112 association subAchObj between
113 Subject[1..*] role sAchieves
114 Object[1..*] role objDone
115 end
116
117 association objTransOutcome between
118 Object[1..*] role objTrans
119 Outcome[1..*] role outCreated
120 end
121
122 association enabEleReqOut between
123 Element[0..*] role enabledElements
124 Outcome[0..1] role requiredOutcomes
125 end
126
127 association eleInASD between
128 ASD[1..*] role diagrams
129 Element[1..*] role elements
130 end
131
132 association refEleParEle between
133 Element[0..*] role refinedElements
134 Element[0..*] role parentElements
135 end
136
137 association relASDs between
138 ASD[0..*] role relatedASD
139 ASD[0..*] role asd
140 end
141
142 association collDiag between
143 Collections[0..*] role coll
144 ASD[1..*] role asdDiags
145 end
146
147 ----------------------------------------------------
148 -- This is an addition to the USE model for
an activity theory language
```

```
149 -- This relation and constraint allow
elements to be defined as equivalent
150
151 association equivElements between
152 Element[0..*] role targetEquivEle
153 Element[0..*] role srcEquivEle
154 end

155
156 association medRelASD between
157 ASD[1] role relevantASD
158 MediatedComposite[1..*] role mComposits
159 end
160

161 constraints
162 context ASD
163 inv relatedIsRefinedEnabled: self.relatedASD -> forAll (a:ASD |
164 (self.elements -> select (oclIsTypeOf(DivisionOfLabor)) ->
165 exists (e:Element | e.oclAsType (DivisionOfLabor).refinedDiagrams -> includes (a))) or
166 (self.elements -> select (oclIsTypeOf(Outcome)) ->
167 exists (e:Element | e.oclAsType (Outcome).enabledElements.diagrams -> includes (a))))
168
169
170 context Element
171 inv noEleRefLoops: self.refinedElements->forAll(e : Element|self <> e)
172
173 context Outcome
174 inv enabledEleTypes: self.enabledElements->forAll(e : Element|e.oclIsTypeOf(DivisionOfLabor)
175 or e.oclIsTypeOf(Rule) or e.oclIsTypeOf(Tool)
176 or e.oclIsTypeOf(Subject)
177 or e.oclIsTypeOf(CommunityMember))
178 and self.enabledElements->forAll(e : Element|e.diagrams->intersection(self.diagrams)->isEmpty())
179
180 context ASD
181 inv asdHasEleTypes: self.elements->exists(e : Element|e.oclIsTypeOf(Tool))
182 and self.elements->exists(e : Element|e.oclIsTypeOf(Rule))
183 and self.elements->exists(e : Element|e.oclIsTypeOf(DivisionOfLabor))
184 and self.elements->exists(e : Element|e.oclIsTypeOf(Subject))
185 and self.elements->exists(e : Element|e.oclIsTypeOf(CommunityMember))
186 and self.elements->exists(e : Element|e.oclIsTypeOf(Object))
187 and self.elements->exists(e : Element|e.oclIsTypeOf(Outcome))
188
189 context Element
190 inv refinedEleSameType: self.refinedElements ->
191 forAll(e : Element|self.oclIsTypeOf(Tool) implies e.oclIsTypeOf(Tool)
192 and self.oclIsTypeOf(Rule) implies e.oclIsTypeOf(Rule)
193 and self.oclIsTypeOf(DivisionOfLabor) implies e.oclIsTypeOf(DivisionOfLabor)
194 and self.oclIsTypeOf(Subject) implies e.oclIsTypeOf(Subject)
195 and self.oclIsTypeOf(CommunityMember) implies e.oclIsTypeOf(CommunityMember)
196 and self.oclIsTypeOf(Object) implies e.oclIsTypeOf(Object)
197 and self.oclIsTypeOf(Outcome) implies e.oclIsTypeOf(Outcome)
198 and self.oclIsTypeOf(Motivation) implies e.oclIsTypeOf(Motivation))
199
200 context ASD
201 inv noRelatedAsdLoops: self.relatedASD->forAll(asd : ASD|self <> asd)
202
203
204 context MediatedComposite
205 inv constituents: self.scoEle->forAll(e1,e2:MediatedEle | (e1 <> e2)
206 implies ((e1.oclIsTypeOf(Subject) and not (e2.oclIsTypeOf(Subject)))
207 or (e1.oclIsTypeOf(CommunityMember) and not (e2.oclIsTypeOf(CommunityMember)))
208 or (e1.oclIsTypeOf(Object) and not (e2.oclIsTypeOf(Object)))))
```

```
209
210 context Tool
211 inv sUsesTachieveObj: self.mediates->exists(m:MediatedComposite |
212 m.scoEle->exists(e1,e2:MediatedEle|e1.oclIsTypeOf(Subject)
213 and e2.oclIsTypeOf(Object)))
214
215 ----------------------------------------------------
216 -- This is an addition to the USE model for an activity theory language
217 -- This relation and constraint allow elements to be defined as equivalent
218
219 context Element
220 inv equivalentEleSameType: self.targetEquivEle->forAll(e : Element|self.oclIsTypeOf(Tool)
221 implies e.oclIsTypeOf(Tool)
222 and self.oclIsTypeOf(Rule) implies e.oclIsTypeOf(Rule) and self.oclIsTypeOf(DivisionOfLabor)
223 implies e.oclIsTypeOf(DivisionOfLabor) and self.oclIsTypeOf(Subject)
224 implies e.oclIsTypeOf(Subject) and self.oclIsTypeOf(CommunityMember)
225 implies e.oclIsTypeOf(CommunityMember) and self.oclIsTypeOf(Object)
226 implies e.oclIsTypeOf(Object) and self.oclIsTypeOf(Outcome) implies e.oclIsTypeOf(Outcome)
227 and self.oclIsTypeOf(Motivation) implies e.oclIsTypeOf(Motivation))
228 ----------------------------------------------------
229
230 context ASD
231 inv mediationInOneASD: ASD.allInstances() ->
232 forAll (a:ASD | a.mComposits ->
233 forAll (mc:MediatedComposite | (mc.mediatedBy ->
234 forAll (e:MediatingEle | a.elements -> includes (e)) )
235 and (mc.scoEle ->
236 forAll (f:MediatedEle | a.elements -> includes (f)) ) ) )
237
```

Listing 1. USE Model for AT Language V5 Meta-model.

References

[Eisen] L. Eisen, J.M. Bieman, S. Ghosh, and S. Lozano-Fuentes, “Use of cell phones for field data capture in a Dengue Decision Support System”, Research Project supported by Award Number R21AI080567 of the National Institute of Allergy And Infectious Diseases, http://www.cs.colostate.edu/ddss/, 2009-2012.

[Engeström] Y. Engeström, *Learning by expanding*, Helsinki: Orienta-Konsultit (1987)

[Lozano] S. Lozano-Fuentes, S. Ghosh, J. M. Bieman, D. Sadhu, L. Eisen, F. Wedyan, E. Hernandez-Garcia, J. Garcia-Rejon, D. Tep-Chel, “Using Cell Phones for Mosquito Vector Surveillance and Control”, *Proceedings 24th International Conference on Software Engineering & Knowledge Engineering (SEKE’12)*, Knowledge Systems Institute Graduate School, pp 763-767, 2012.

[USE] The UML-based Specification Environment, http://sourceforge.net/apps/mediawiki/useocl/index.php?title=Main_Page