LMP: Logic Model Processing

Prolog Day Symposium
Paris, 10 Nov 2022

P. Dissaux
Ellidiss Technologies, 24, quai de la douane,
29200 Brest, Brittany, France
A HOOD model is a representation of a System to Design in terms of objects, classes, generics and relationships within a system configuration. In order to ensure consistency of these representations, HOOD defines visibility and scoping rules.

The term module is used to designed object, class and generic.

AG-1. A module is mapped into a package named as the object.

Optional rules shall specify the conditions for the generation of library units, nested units, subunits, (private) child units or protected units. By default child objects are mapped into library units and operations into associated bodies.

AG-2. A provided operation of a terminal module is mapped into the declaration of a subprogram specification in the package specification and in a subprogram body in the package body associated with the object.

Optional rules may specify the condition for the generation of subunits\(^\text{17}\). By default they are nested in the package body associated to the object.
isObject('philosophers','PASSIVE','SYSTEM_CONFIGURATION').

isProvided('Start','OPERATION','philosophers').

isObject('room','ACTIVE','philosophers').

isProvided('start_serving','OPERATION','room').

isImplementedBy('Start','OPERATION','philosophers',
'start_serving','room',1).

...
16.2 INCLUDE RELATIONSHIP

The include relationship describes modular breakdown of a MODULE into other MODULEs.

I-1 A PARENT is a MODULE that INCLUDEs at least one other MODULE.
I-2 A CHILD is a MODULE which is INCLUDEd by a PARENT.
I-3 When a PARENT is broken down into CHILDren, they shall provide together the same functionality.
I-4 A CHILD shall not have more than one PARENT.
I-5 A MODULE shall not INCLUDE itself.

I-6 Each OPERATION provided by a PARENT shall be IMPLEMENTED BY one OPERATION provided by one of its CHILDren.
I-6 Each OPERATION provided by a PARENT shall be IMPLEMENTED_BY one OPERATION provided by one of its CHILDren.

/* HRM 4 rule I6: 
Each OPERATION provided by a PARENT shall be IMPLEMENTED_BY one OPERATION provided by one of its CHILDren. */

errI6(X,U) :- isProvided(U,'OPERATION',X),
  not(isImplementedBy(U,'OPERATION',X,_,_)).

checkI :- isNotTerm(X), errI6(X,U),
  write('ERROR : Operation : '), write(U),
  write(' provided by not terminal object : '), write(X),
  write(' should be implemented by a child object ! (I6)'), nl.
checkI :- printf('--- > rule I6 checked...').

/* utility rules */
isTerm(Y) :- hoodObject(Y,_,_), not(hoodObject(_,_,Y)).
isNotTerm(Y) :- hoodObject(Y,_,_), isParent(Y).
isParent(Y) :- hoodObject(_,_,Y), !.
## LMP realizations for HOOD
**Airbus 340/380/350**

<table>
<thead>
<tr>
<th>Rules Base</th>
<th>Tool</th>
<th>DO 178 Qualification (verification tools)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HOOD to Ada</td>
<td>Stood</td>
<td></td>
</tr>
<tr>
<td>HOOD to C/Asm</td>
<td>Stood</td>
<td></td>
</tr>
<tr>
<td>HOOD Checker</td>
<td>Stood</td>
<td>Yes</td>
</tr>
<tr>
<td>HOOD to Document</td>
<td>Stood</td>
<td></td>
</tr>
<tr>
<td>HOOD to Frama-C</td>
<td>Stood</td>
<td>Yes</td>
</tr>
<tr>
<td>HOOD to Caveat</td>
<td>Stood</td>
<td>Yes</td>
</tr>
</tbody>
</table>
LMP for Model Driven Engineering

Software Model Driven Engineering

- Observe: model exploration, queries and views
- Verify static properties: rules checkers
- Perform model transformations:
  - Refinement along the development life-cycle (e.g. system to software)
  - Verification: transform a descriptive model into a verification model
  - Source code generation (model to code)
  - Source code reverse engineering (code to model)
  - Documentation generation

Logic Model Processing applied to Model Driven Engineering

- Metamodel or modeling language specification
  - Is an abstraction of
  - Model
    - Is an abstraction of
  - Source code

Examples:
- HOOD
- Ada
LMP: a generic model processing approach

LMP development and runtime process:
• Any Modeling (or Programing) Language can be represented by a set of Prolog Fact Definitions
• Any Model can be represented by a populated Prolog Facts Base
• Any Model processing action (queries, constraints, transformations, …) can be represented by a Prolog Rules Base
• Prolog facts and rules base can be merged together to get the expected result
LMP runtime process

Models to be processed

Input Model
in files
or
in memory

parser or generator

Facts base

Textual or byte code

prolog engine

Model processing result

Output Model
Check Report
Source code
...

Parsers:
- aadlrev
- xmlrev
- adarev
- crev

Generators:
- Stood
- AADL Inspector
- C library

Rules bases

processing library:
- Model analysis
- Model exploration
- M2M transformation
- M2T transformation

Ellidiss Technologies
www.ellidiss.com
LMP parsers for tag-based models (XMI/XML) e.g. ReqIF

Fragment of the meta-model: XML Schema Definition (XSD)

```xml
<xsd:schema ... >
  <xsd:complexType name="SPEC-OBJECT">
    ...
    <xsd:attribute name="DESC" type="xsd:string" use="optional"/>
    <xsd:attribute name="IDENTIFIER" type="xsd:ID" use="required"/>
    <xsd:attribute name="LAST-CHANGE" type="xsd:dateTime" use="required"/>
    <xsd:attribute name="LONG-NAME" type="xsd:string" use="optional"/>
  </xsd:complexType>
  ...
</xsd:schema>
```

Corresponding prolog Fact Definition:

```prolog
isSpecObject(Desc, Identifier, LastChange, LongName).
```
LMP parsers
for token based models
e.g. AADL

Fragment of the meta-model: Backus-Naur Form (BNF)

...  
component_type ::=  
    component_category component_identifier  
    { property }*  
    end component_identifier;  
property ::=  
    property_name => property_value;  
...

Corresponding prolog Facts definition:

isComponentType(ComponentCategory,ComponentIdentifier).
isProperty(ComponentIdentifier,PropertyName,PropertyValue).
1. Merge together the two facts bases:

```prolog
isSpecObject('',='',='',Temp_Lower_Bound).
isSpecObject('',='',='',Temp_Upper_Bound).
...
isComponentType('Thread','Thermostat').
isProperty('Thermostat','Coverage',Temp_Lower_Bound).
isProperty('Thermostat','Coverage',Temp_Upper_Bound).
```

2. Add the rules base:
   "check requirements coverage:"

```prolog
checkCoverage :-
    isSpecObject(_,_,_,R),
    isComponentType(_,C),
    not(isProperty(C,'Coverage',R)),
    writeErrorMessage(R).
```

3. Run the Prolog engine
# LMP realizations for AADL\(^{(1)}\)

<table>
<thead>
<tr>
<th>LMP rules</th>
<th>category</th>
</tr>
</thead>
<tbody>
<tr>
<td>AADL semantic rules</td>
<td>model checker</td>
</tr>
<tr>
<td>AADL instance builder</td>
<td>model exploration</td>
</tr>
<tr>
<td>AADL ARINC 653 rules</td>
<td>model checker</td>
</tr>
<tr>
<td>UML MARTE to AADL</td>
<td>model transformation</td>
</tr>
<tr>
<td>SysML to AADL</td>
<td>model transformation</td>
</tr>
<tr>
<td>Capella to AADL</td>
<td>model transformation</td>
</tr>
<tr>
<td>FACE(^{(2)}) to AADL</td>
<td>model transformation</td>
</tr>
<tr>
<td>AADL to Cheddar</td>
<td>model verification (timing analysis)</td>
</tr>
<tr>
<td>AADL to Marzhin</td>
<td>model verification (simulation)</td>
</tr>
<tr>
<td>AADL to OpenPSA</td>
<td>model verification (safety analysis)</td>
</tr>
<tr>
<td>AADL printer</td>
<td>model unparser</td>
</tr>
<tr>
<td>LAMP checker</td>
<td>online model processing</td>
</tr>
</tbody>
</table>

---

(1) Architecture Analysis and Design Language (AADL) is a modeling standard of the SAE (AS-5506)

(2) FACE is a trademark of the Open Group
package Ellidiss::ERTS2020::paper26::e1
public

abstract A
-- a LAMP goal at component level

annex LAMP {**
/* standard prolog syntax */
checkSecurityRules
**};
end A;

-- LAMP rules at package level
annex LAMP {**
/* standard prolog syntax */
checkSecurityRules :-
... 
**};
end Ellidiss::ERTS2020::paper26::e1;
User-customizable Model Transformations

FACE™ Technical Standard, Edition 3.0, J5

FACE model

FACE metamodel

Online (fixed rules)

Online (modifiable rules)

Off-line (done once)

FACE-AADL mapping customization

ELLIDISS
Technologies
w w w . e l l i d i s s . c o m
Tool integration: AADL Inspector

Rules library: LAMPLib

Control panel and console: LAMPLab
Benefits of the LMP approach

- **Generic** solution for:
  - Model API
  - Model constraints
  - Model transformations
  - Model exploration and architectural reasoning
- **Standard** prolog language (ISO/IEC 13211-1)
- **Independent**: compatible with the main meta-modelling formats (BNF, XSD, MOF, Ecore)
- **Interpreted**: supports both off-line and online processing (e.g. LAMP)
- **Declarative**: fits well with multi-steps incremental development processes
- **Modular**:
  - separate fact and rules bases
  - rules bases transitivity: e.g. SysML to code : SysML to AADL and AADL to code
- **Formal** (boolean logic): appropriate for tool qualification
- **Flexible**:
  - Supports heterogeneous models
  - Supports incomplete models (subsets)
  - Supports erroneous models (debugging)
- **Industrial** return of experience of many off-line processing tools:
  - Airbus: LMP applied for the verification of DO-178 certified projects (A380, A350)
  - European Space Agency: used in the TASTE tool-chain
  - Honeywell: architecture reasoning
  - Ellidiss: AADL Inspector model adaptors and Stood code generators
  - Commercial support
- **Sustainable** project started almost 30 years ago and still relevant and efficient
Conclusion

- The Logic Model Processing (LMP in short) approach has been gradually elaborated during the last three decades.

- These realizations are guided by requirements coming from the aerospace industry.

- It mostly consists of the use of existing Prolog language technology in a particular application domain (implementation of Model Driven Engineering development tools).

- Ellidiss Technologies embeds LMP inside its own commercial products and R&D developments to efficiently implement most of the required «model processing» features.

- Model Driven Engineering is more and more applied in various domains of application (System Engineering) and contributes to the digitalization of the industry. LMP feedback shows that Prolog can play a significant role in this area.