UNIVERSIDAD DE ALMERÍA

Transformation and Validation with SWRL and OWL of ODM-based Models

Jesús M. Almendros-Jiménez and Luis Iribarne

Universidad de Almería.
{jalmen,liribarne}@ual.es

2nd International Conference on Model & Data Engineering (MEDI2012), October 3 - 5, 2012, Poitiers, Futuroscope - France

Table of contents

Motivation

- Model Driven Software Engineering: MDA, UML, DSLs
- Model Transformation (M2M,M2T), Code Generation

UNIVERSIDAD DE ALMERÍA

Motivation

- Model Driven Software Engineering: MDA, UML, DSLs
- Model Transformation (M2M,M2T), Code Generation
- Models, Meta-models and Meta-meta-models

UNIVERSIDAD DE ALMERÍA

Motivation

- Model Driven Software Engineering: MDA, UML, DSLs
- Model Transformation (M2M,M2T), Code Generation
- Models, Meta-models and Meta-meta-models
- Ontology Driven Model Transformation

UNIVERSIDAD DE ALMERÍA

Motivation

- Model Driven Software Engineering: MDA, UML, DSLs
- Model Transformation (M2M,M2T), Code Generation
- Models, Meta-models and Meta-meta-models
- Ontology Driven Model Transformation
- OWL based Representation of UML Models: Ontology Definition Meta-model (ODM)

UNIVERSIDAD DE ALMERÍA

Motivation

- Model Driven Software Engineering: MDA, UML, DSLs
- Model Transformation (M2M,M2T), Code Generation
- Models, Meta-models and Meta-meta-models
- Ontology Driven Model Transformation
- OWL based Representation of UML Models: Ontology Definition Meta-model (ODM)
- OWL and SWRL Semantic Web Languages

UNIVERSIDAD DE ALMERÍA

Motivation

- Model Driven Software Engineering: MDA, UML, DSLs
- Model Transformation (M2M,M2T), Code Generation
- Models, Meta-models and Meta-meta-models
- Ontology Driven Model Transformation
- OWL based Representation of UML Models: Ontology Definition Meta-model (ODM)
- OWL and SWRL Semantic Web Languages

UNIVERSIDAD DE ALMERÍA

State of Art

- Meta-meta-model: MOF
- Model Transformations: ATL transformation language
- Model Validation: OCL
- Meta-meta-model: ODM
- Model Transformation: SWRL
- Model Validation: OWL/SWRL

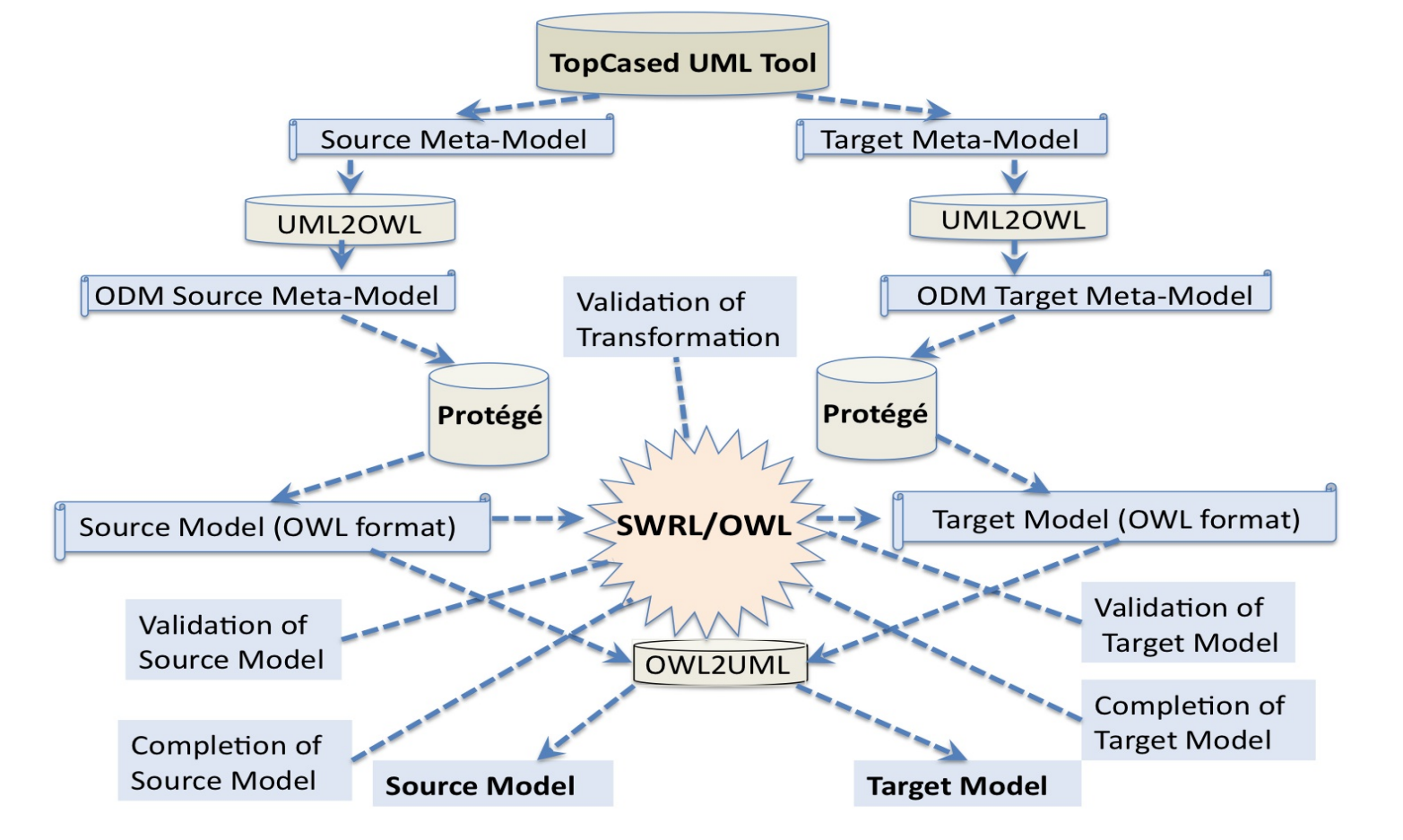
UNIVERSIDAD DE ALMERÍA

State of Art

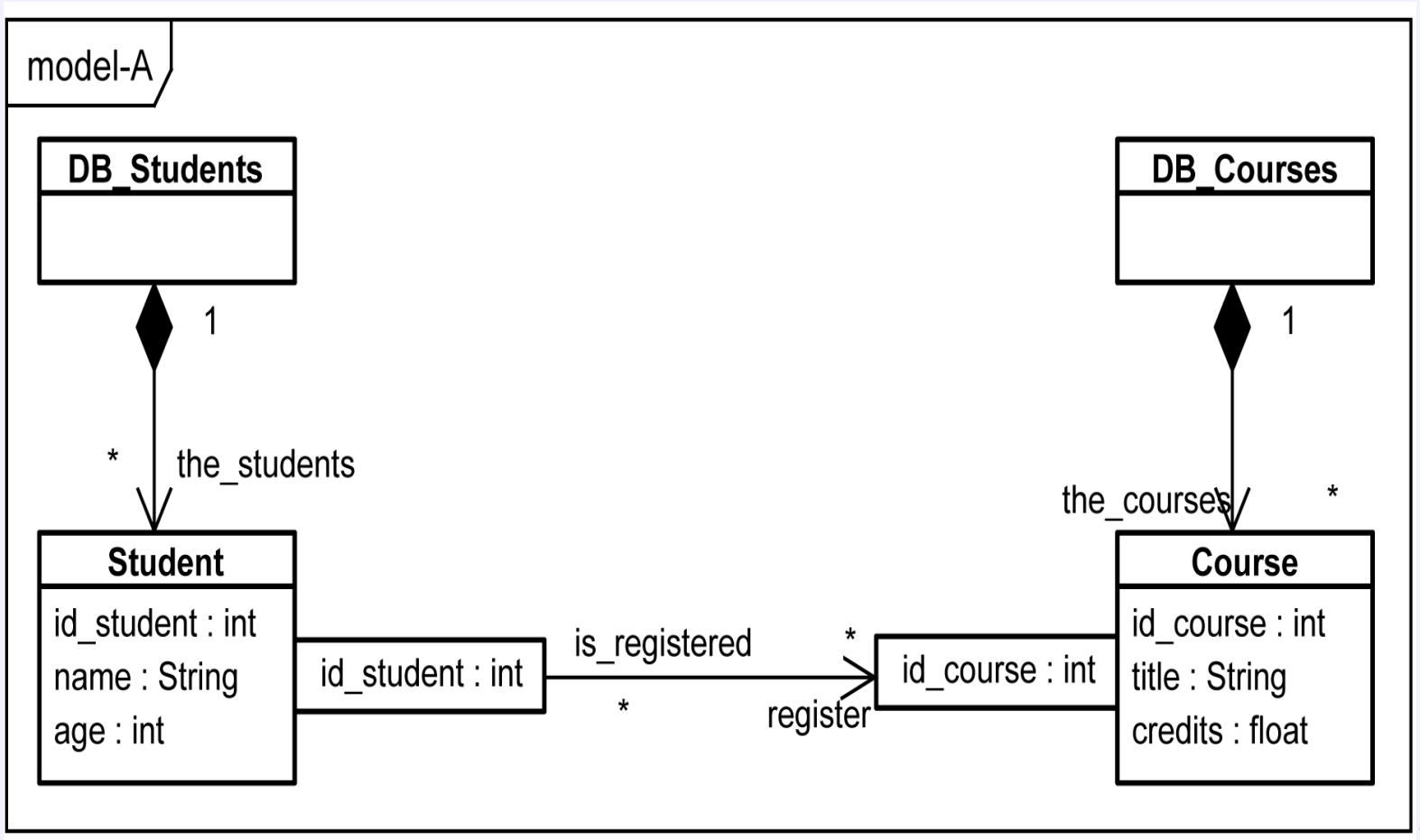
- Meta-meta-model: MOF
- Model Transformations: ATL transformation language
- Model Validation: OCL
- Meta-meta-model: ODM
- Model Transformation: SWRL
- Model Validation: OWL/SWRL

UNIVERSIDAD DE ALMERÍA

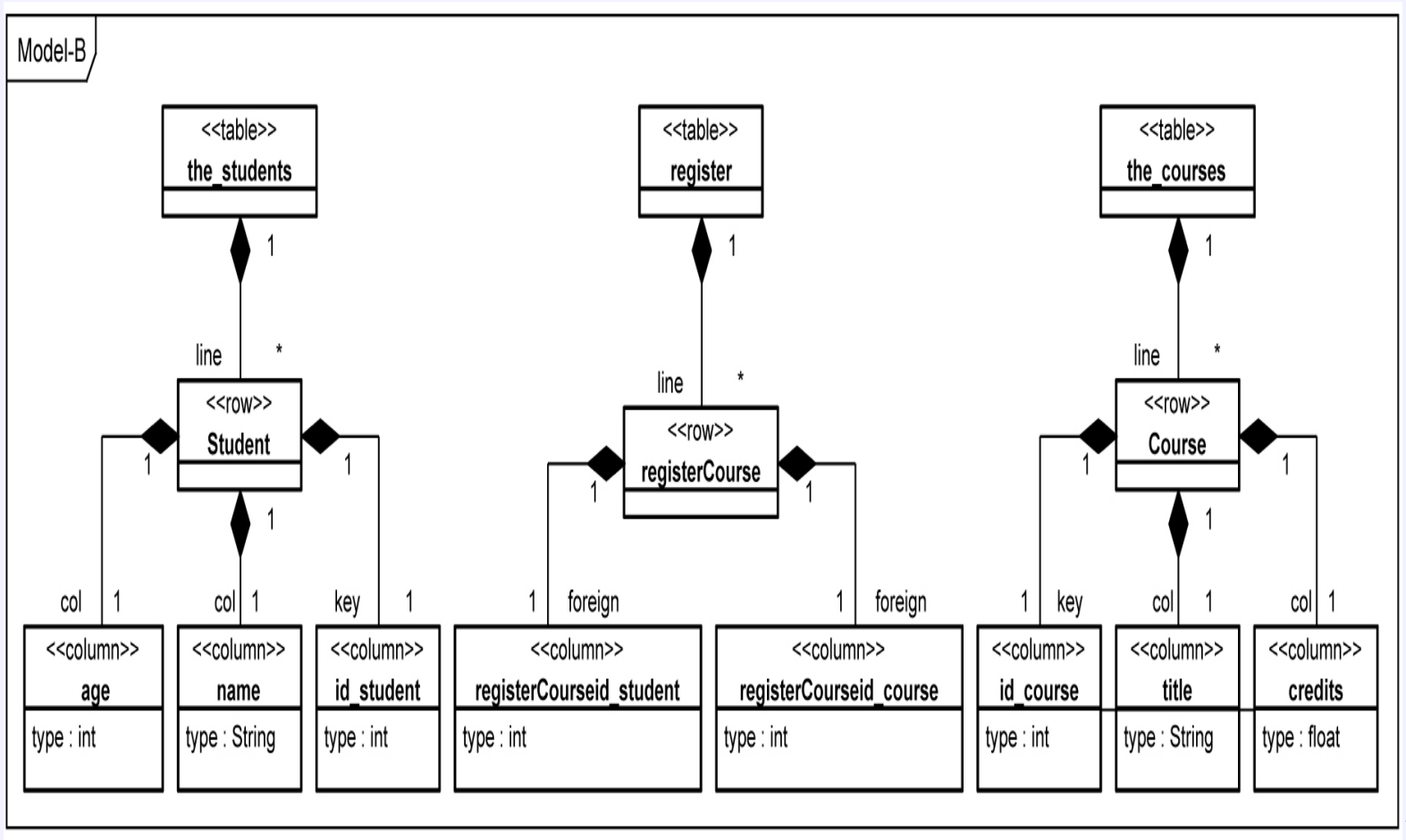
Model Transformation



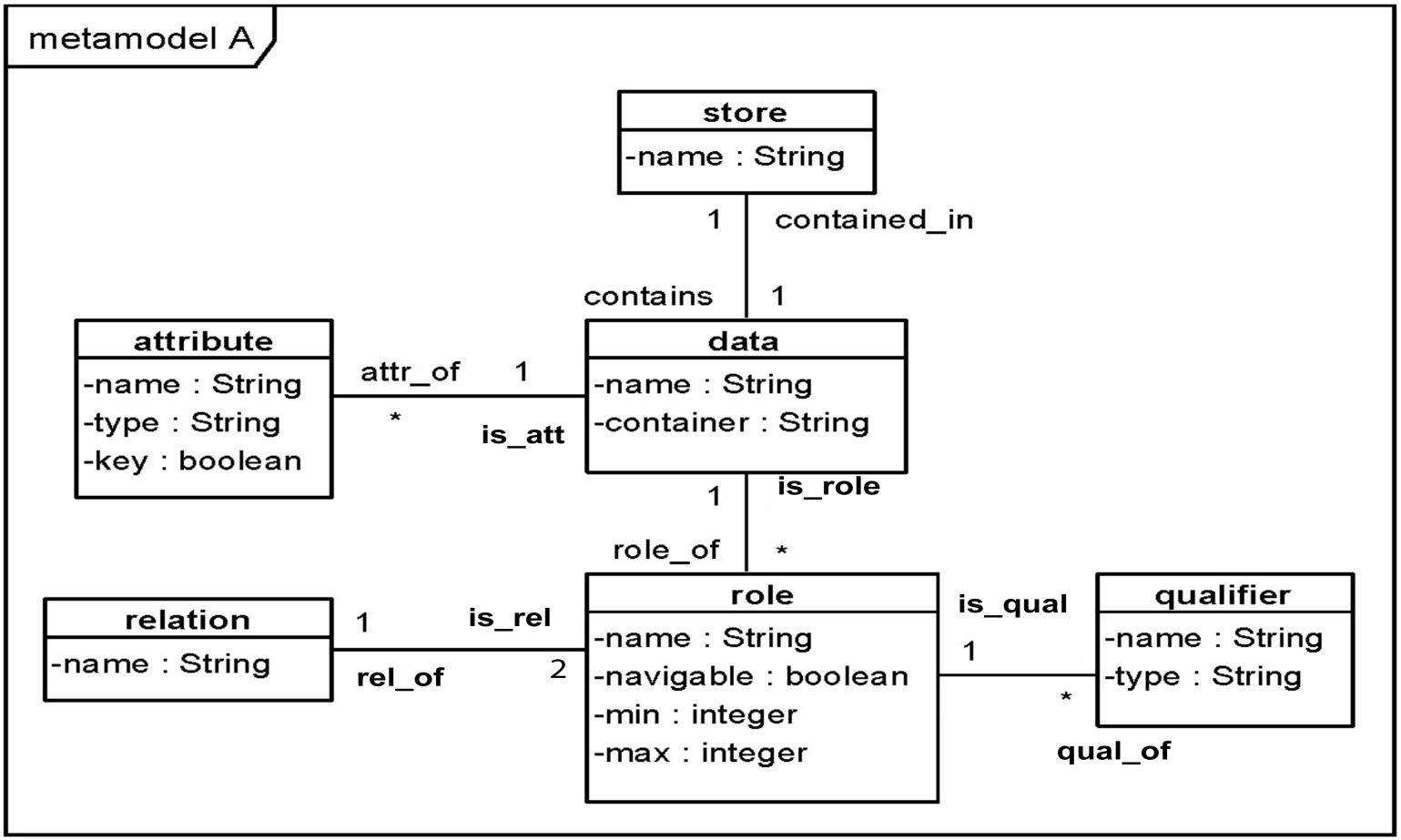
Source Model



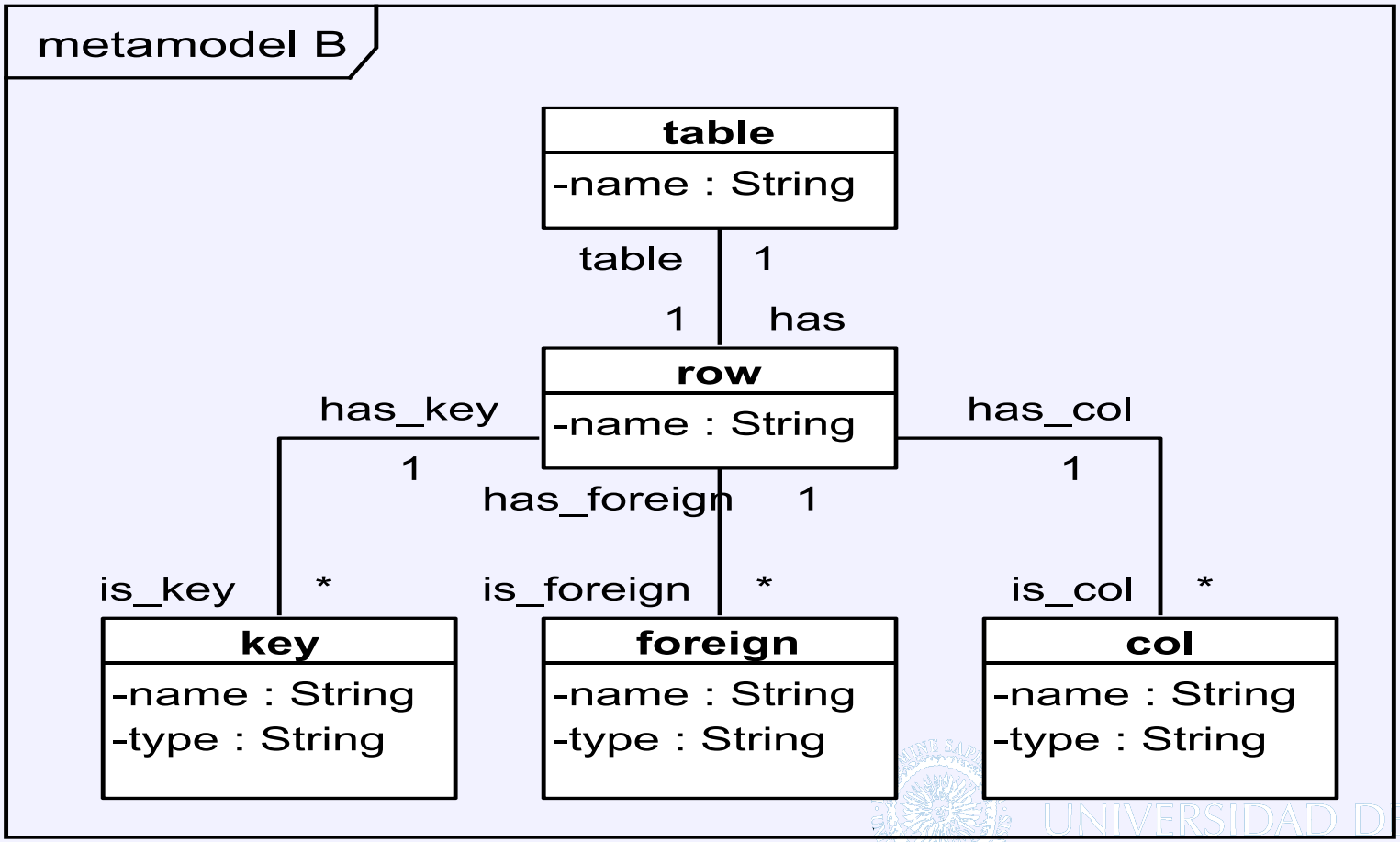
Target Model



Source Meta-Model



Target Meta-Model



Ontology Driven Model Transformation

- OWL representation of meta-models/models: ODM
- Source Model Completion with OWL/SWRL

UNIVERSIDAD DE ALMERÍA

Ontology Driven Model Transformation

- OWL representation of meta-models/models: ODM
- Source Model Completion with OWL/SWRL
- Source to Target Model (Partial) Transformation with SWRL

UNIVERSIDAD DE ALMERÍA

Ontology Driven Model Transformation

- OWL representation of meta-models/models: ODM
- Source Model Completion with OWL/SWRL
- Source to Target Model (Partial) Transformation with SWRL
- Target Model Completion with OWL/SWRL

UNIVERSIDAD DE ALMERÍA

Ontology Driven Model Transformation

- OWL representation of meta-models/models: ODM
- Source Model Completion with OWL/SWRL
- Source to Target Model (Partial) Transformation with SWRL
- Target Model Completion with OWL/SWRL
- Extended SWRL with Built-ins: Handling of URIs: newURI and Collections: makeSet, makeBag, element, notElement.

UNIVERSIDAD DE ALMERÍA

Ontology Driven Model Transformation

- OWL representation of meta-models/models: ODM
- Source Model Completion with OWL/SWRL
- Source to Target Model (Partial) Transformation with SWRL
- Target Model Completion with OWL/SWRL
- Extended SWRL with Built-ins: Handling of URIs: newURI and Collections: makeSet, makeBag, element, notElement.

UNIVERSIDAD DE ALMERÍA

Model Validation

- Source and Target Model Validation
- Cross Validation of Source and Target models

UNIVERSIDAD DE ALMERÍA

Model Validation

- Source and Target Model Validation
- Cross Validation of Source and Target models
- Pre-conditions, post-conditions and invariants

UNIVERSIDAD DE ALMERÍA

Model Validation

- Source and Target Model Validation
- Cross Validation of Source and Target models
- Pre-conditions, post-conditions and invariants
- Structural Constraints (SC)

UNIVERSIDAD DE ALMERÍA

Model Validation

- Source and Target Model Validation
- Cross Validation of Source and Target models
- Pre-conditions, post-conditions and invariants
- Structural Constraints (SC)
- Semantic Requirements (SR)

UNIVERSIDAD DE ALMERÍA

Model Validation

- Source and Target Model Validation
- Cross Validation of Source and Target models
- Pre-conditions, post-conditions and invariants
- Structural Constraints (SC)
- Semantic Requirements (SR)
- Well-formedness (WF)

UNIVERSIDAD DE ALMERÍA

Model Validation

- Source and Target Model Validation
- Cross Validation of Source and Target models
- Pre-conditions, post-conditions and invariants
- Structural Constraints (SC)
- Semantic Requirements (SR)
- Well-formedness (WF)
- Transformation Requirements (TR)

UNIVERSIDAD DE ALMERÍA

Model Validation

- Source and Target Model Validation
- Cross Validation of Source and Target models
- Pre-conditions, post-conditions and invariants
- Structural Constraints (SC)
- Semantic Requirements (SR)
- Well-formedness (WF)
- Transformation Requirements (TR)

UNIVERSIDAD DE ALMERÍA

Source Model Validation (Pre-conditions)

- (1) All attributes of a data have distint names (SR) (WF)
- (2) Each data has a unique key attribute (SR) (TR)

UNIVERSIDAD DE ALMERÍA

Source Model Validation (Pre-conditions)

- (1) All attributes of a data have distint names (SR) (WF)
- (2) Each data has a unique key attribute (SR) (TR)
- (3) Each data has a key attribute (SR) (TR)

Source Model Validation (Pre-conditions)

- (1) All attributes of a data have distint names (SR) (WF)
- (2) Each data has a unique key attribute (SR) (TR)
- (3) Each data has a key attribute (SR) (TR)
- (4) Each attribute is associated to exactly one data
- (5) Each data is contained in exactly one store (SC) (WF)
- (6) All data have distinct names (SR) (TR)
- (7) All data have distinct containers (SR) (TR)
- (8) Each qualifier is associated to exactly one role (SC) (TR)
- (9) All qualifier names of a data are distinct (SR) (TR)
- (10) All qualifiers are key attributes (SR) (WF)
- (11) Each relation has two roles (SC) (WF)
- (12) All relation names are distinct (SR) (WF)
- (13) Each role is associated to exactly one relation (SC) (TR)
- (14) Each role is associated to exactly one data (SC) (TR)
- (15) All role names of a data are distinct (SR) (TR)
- (16) Each store is associated to exactly one data (SC) (WF)

Source Model Validation (Pre-conditions)

- (1) All attributes of a data have distint names (SR) (WF)
- (2) Each data has a unique key attribute (SR) (TR)
- (3) Each data has a key attribute (SR) (TR)
- (4) Each attribute is associated to exactly one data
- (5) Each data is contained in exactly one store (SC) (WF)
- (6) All data have distinct names (SR) (TR)
- (7) All data have distinct containers (SR) (TR)
- (8) Each qualifier is associated to exactly one role (SC) (TR)
- (9) All qualifier names of a data are distinct (SR) (TR)
- (10) All qualifiers are key attributes (SR) (WF)
- (11) Each relation has two roles (SC) (WF)
- (12) All relation names are distinct (SR) (WF)
- (13) Each role is associated to exactly one relation (SC) (TR)
- (14) Each role is associated to exactly one data (SC) (TR)
- (15) All role names of a data are distinct (SR) (TR)
- (16) Each store is associated to exactly one data (SC) (WF)

Target Model Validation (Post-conditions)

- (17) All column names of a row are distinct (SR) (WF)
- (18) All foreign key names of a row are distinct (SR) (WF)

UNIVERSIDAD DE ALMERÍA

Target Model Validation (Post-conditions)

- (17) All column names of a row are distinct (SR) (WF)
- (18) All foreign key names of a row are distinct (SR) (WF)
- (19) All key names of a row are distinct (SR) (WF)
- (20) All foreign keys of a row are keys of another row (SR) (WF)
- (21) Each table is associated to exactly one row (SC) (WF)
- (22) Each row is associated to exactly one table (SC) (WF)
- (23) Each key is associated to exactly one row (SC) (TR)
- (24) Each col is associated to exactly one row (SC) (TR)
- (25) Each foreign is associated to exactly one row (SC) (TR)
- (26) All table names are distinct (SR) (WF)
- (27) All row names are distinct (SR) (WF)
- (28) All rows have exactly one key (SC) (TR)
- (29) All rows have either all keys and cols or all foreigns (SR) (TR)

Target Model Validation (Post-conditions)

- (17) All column names of a row are distinct (SR) (WF)
- (18) All foreign key names of a row are distinct (SR) (WF)
- (19) All key names of a row are distinct (SR) (WF)
- (20) All foreign keys of a row are keys of another row (SR) (WF)
- (21) Each table is associated to exactly one row (SC) (WF)
- (22) Each row is associated to exactly one table (SC) (WF)
- (23) Each key is associated to exactly one row (SC) (TR)
- (24) Each col is associated to exactly one row (SC) (TR)
- (25) Each foreign is associated to exactly one row (SC) (TR)
- (26) All table names are distinct (SR) (WF)
- (27) All row names are distinct (SR) (WF)
- (28) All rows have exactly one key (SC) (TR)
- (29) All rows have either all keys and cols or all foreigns (SR) (TR)

Transformation Validation (Invariants)

- (30) Key and column names and types are names and types of attributes
- (31) Table names are either container names or role names

UNIVERSIDAD DE ALMERÍA

Transformation Validation (Invariants)

- (30) Key and column names and types are names and types of attributes
- (31) Table names are either container names or role names
- (32) Row names are data names or concatenations of role names and data
- (33) Foreign names are concatenations of roles, data and key

Transformation Validation (Invariants)

- (30) Key and column names and types are names and types of attributes
- (31) Table names are either container names or role names
- (32) Row names are data names or concatenations of role names and data
- (33) Foreign names are concatenations of roles, data and key

ODM representation of meta-models/models

```
<store rdf:about="#01_DB_Students_store">
        <rdf:type rdf:resource="&owl;Thing"/>
        <store.name rdf:datatype="&xsd;string">DB_Students
        </store.name>
        <store.contains rdf:resource="#02_Student_data"/>
</store>
<data rdf:about="#02_Student_data">
        <rdf:type rdf:resource="&owl;Thing"/>
        <data.name rdf:datatype="&xsd;string">Student</data.name>
        <data.container rdf:datatype="&xsd;string">the_students
        </data.container>
        <data.contained_in rdf:resource="#01_DB_Students_store"/>
        <data.attr_of rdf:resource="#03_id_student_attribute"/>
        <data.attr_of rdf:resource="#04_name_attribute"/>
        <data.attr_of rdf:resource="#05_age_attribute"/>
        <data.role_of rdf:resource="#06_is_registered_role"/>
</data>
```

Source Model Completion

Case	SWRL Rule
(c1)	*mmA:attribute(?C)* $\wedge$ *mmA:key(?C,?D)* $\wedge$*equal(?D,true)* $\wedge$ *mmA:name(?C,?N)* $\wedge$ *mmA:type(?C,?T)* $\rightarrow$ **mmA:keyAttribute***(?C)* $\wedge$ **mmA:key_name***(?C,?N)* $\wedge$ **mmA:key_type***(?C,?T)*
(c2)	*mmA:attribute(?C)* $\wedge$ *mmA:key(?C,?D)* $\wedge$ *equal(?D,false)* $\wedge$ *mmA:name(?C,?N)* $\wedge$ *mmA:type(?C,?T)* $\rightarrow$ **mmA:nonkeyAttribute***(?C)* $\wedge$ **mmA:nonkey_name***(?C,?N)* $\wedge$ **mmA:nonkey_type***(?C,?T)*
(c3)	*mmA:data(?A)* $\wedge$ *mmA:role_of(?A,?C)* $\wedge$ *mmA:navigable(?C,?E)* $\wedge$ *equal(?E,true)* $\wedge$ *mmA:rel_of(?C,?D)* $\wedge$ *mmA:is_rel(?D,?D2)* $\wedge$ *owl:differentFrom(?D2,?C)* $\wedge$ *mmA:equal_of(?D2,?D3)* $\wedge$ *mmA:name(?D3,?N)* $\wedge$ *mmA:type(?D3,?T)* $\rightarrow$ **mmA:navigable_role***(?C)* $\wedge$ **mmA:inv_qualifier_name***(?C,?N)* $\wedge$ **mmA:inv_qualifier_type***(?C,?T)*

Validation Source Model

Case	SWRL Rule
(v1)	*mmA:attr_of(?Data,?Att1)* $\wedge$ *mmA:attr_of(?Data,?Att2)* $\wedge$ *mmA:name(?Att1,?Name1)* $\wedge$ *mmA:name(?Att2,?Name2)* $\wedge$ *owl:differentFrom(?Att1,?Att2)* $\wedge$ *equal(?Name1,?Name2)* $\rightarrow$ **val:duplicated_attribute_name***(?Att1)* $\wedge$ **val:duplicated_attribute_name***(?Att2)*
(v6)	*mmA:data(?Data1)* $\wedge$ *mmA:data(?Data2)* $\wedge$ *owl:differentFrom(?Data1,?Data2)* $\wedge$ *mmA:name(?Data1,?Name1)* $\wedge$ *mmA:name(?Data2,?Name2)* $\wedge$ *equal(?Name1,?Name2)* $\rightarrow$ **val:duplicated_data_name***(?Data1)* $\wedge$ **val:duplicated_data_name***(?Data2)*
(v7)	*mmA:data(?Data1)* $\wedge$ *mmA:data(?Data2)* $\wedge$ *owl:differentFrom(?Data1,?Data2)* $\wedge$ *mmA:container(?Data1,?Name1)* $\wedge$ *mmA:container(?Data2,?Name2)* $\wedge$ *equal(?Name1,?Name2)* $\rightarrow$ **val:duplicated_data_container***(?Data1)* $\wedge$ **val:duplicated_data_container***(?Data2)*

Partial Model Transformation

Case	SWRL Rule
(r1)	*mmA:data(?A)* $\wedge$ *mmA:container(?A,?B)* $\wedge$ *newURI(?A,'table1',?C)* $\rightarrow$ **mmB:table**(*?C*) $\wedge$ *mmB:name(?C,?B)*
(r2)	*mmA:navigable_role(?C)* $\wedge$ *mmA:name(?C,?B)* $\wedge$ *newURI(?C,'table2',?D)* $\rightarrow$ **mmB:table**(*?D*) $\wedge$ *mmB:name(?D,?B)*
(r3)	*mmA:data(A)* $\wedge$ *mmA:name(?A,?B)* $\wedge$ *newURI(?A,'row1',?C)* $\rightarrow$ **mmB:row**(*?C*) $\wedge$ *mmB:name(?C,?B)*
(r4)	*mmA:navigable_role(?C)* $\wedge$ *mmA:name(?C,?D)* $\wedge$ *mmA:is_role(?C,?DT)* $\wedge$ *mmA:name(?DT,?B)* $\wedge$ *concatString(?D,?B,?F)* $\wedge$ *newURI(?C,'row2',?G)* $\rightarrow$ **mmB:row**(*?G*) $\wedge$ *mmB:name(?G,?F)*
(r5)	*mmA:data(?A)* $\wedge$ *mmA:attr_of(?A,?B)* $\wedge$ *mmA:nonkeyAttribute(?B)* $\wedge$ *mmA:name(?B,?N)* $\wedge$ *mmA:type(?B,?T)* $\wedge$ *newURI(?B,'col',?D)* $\rightarrow$ **mmB:col**(*?D*) $\wedge$ *mmB:name(?D,?N)* $\wedge$ *mmB:type(?D,?T)*

Completion of Target Model

Case	SWRL Rule
(c4)	*mmB:has(?B,?A)* $\rightarrow$ **mmB:table***(?A,?B)*
(c5)	*mmB:is_key(?B,?A)* $\rightarrow$ **mmB:has_key***(?A,?B)*
(c6)	*mmB:is_foreign(?B,?A)* $\rightarrow$ **mmB:has_foreign***(?A,?B)*
(c7)	*mmB:is_col(?B,?A)* $\rightarrow$ **mmB:has_col***(?A,?B)*

UNIVERSIDAD DE ALMERÍA

Validation of Target Model

Case	SWRL Rule
(v17)	*mmB:row(?Row)* $\wedge$ *mmB:col(?Row,?Col1)* $\wedge$ *mmB:col(?Row,?Col2)* $\wedge$ *mmB:name(?Col1,?Name1)* $\wedge$ *mmB:name(?Col2,?Name2)* $\wedge$ *owl:differentFrom(?Col1,?Col2)* $\wedge$ *equal(?Name1,?Name2)* $\rightarrow$ **val:duplicate_col_name***(?Row)*
(v18)	*mmB:row(?Row)* $\wedge$ *mmB:foreign(?Row,?Col1)* $\wedge$ *mmB:foreign(?Row,?Col2)* $\wedge$ *mmB:name(?Col1,?Name1)* $\wedge$ *mmB:name(?Col2,?Name2)* $\wedge$ *owl:differentFrom(?Col1,?Col2)* $\wedge$ *equal(?Name1,?Name2)* $\rightarrow$ **val:duplicate_foreign_name***(?Row)*
(v19)	*mmB:row(?Row)* $\wedge$ *mmB:key(?Row,?Col1)* $\wedge$ *mmB:key(?Row,?Col2)* $\wedge$ *mmB:name(?Col1,?Name1)* $\wedge$ *mmB:name(?Col2,?Name2)* $\wedge$ *owl:differentFrom(?Col1,?Col2)* $\wedge$ *equal(?Name1,?Name2)* $\rightarrow$ **val:duplicate_key_name***(?Row)*

Cross validation of source and target models

Case	SWRL Rule
(v30)	*mmB:key(?Key)* $\wedge$ *mmB:name(?Key,?Name)* $\wedge$ *mmA:key_name(?Key,?NameKey)* $\wedge$ *makeSet(?NameKey,?Names)* $\wedge$ *notElement(?Name,?Names)* $\rightarrow$ **val: bad_key_name**(*?Key*) *mmB:key(?Key)* $\wedge$ *mmB:type(?Key,?Type)* $\wedge$ *mmA:key_type(?Key,?TypeKey)* $\wedge$ *makeSet(?TypeKey,?Types)* $\wedge$ *notElement(?Type,?Types)* $\rightarrow$ **val: bad_key_type**(*?Key*) *mmB:col(?Col)* $\wedge$ *mmB:name(?Col,?Name)* $\wedge$ *mmA:col_name(?Col,?NameCol)* $\wedge$ *makeSet(?NameCol,?Names)* $\wedge$ *notElement(?Name,?Names)* $\rightarrow$ **val: bad_col_name**(*?Col*) *mmB:col(?Col)* $\wedge$ *mmB:type(?Col,?Type)* $\wedge$ *mmA:col_type(?Col,?TypeCol)* $\wedge$ *makeSet(?TypeCol,?Types)* $\wedge$ *notElement(?Type,?Types)* $\rightarrow$ **val: bad_col_type**(*?Col*)

Conclusions and Future Work

- Ontology Driven Model Transformation
- Transformation, Completion and Validation
- `http://indalog.ual.es/mdd`
- SWRL extended with new built-ins
- Eclipse plugin for ontology driven model transformation