Towards a Framework for Multidirectional Model Transformations

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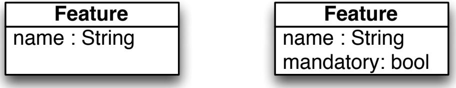
MDE

- In MDE models are the primary development artifact;
- Multiple models must *coexist* in a consistent manner;
- Keeping two of those models consistent has been a main focus of research in BX;
- However, not all consistency relations can be decomposed into the BX scenario.

QVT-R

- QVT-R is able to specify consistency between any number of models;
- The standard semantics has known issues;
- Extensive work has been done on the bidirectional scenario;
- However, the multidirectional scenario has been disregarded.

Multidirectional Scenario



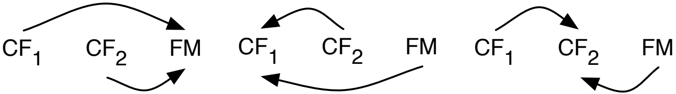
- Consider the (very simplified) problem of keeping a feature model consistent with k configurations;
- Mandatory features MF:
  - $MF_{\mathtt{CF}_i}$: every mandatory feature is selected in every $\mathtt{CF}_i$;
  - $MF_{\mathtt{FM}}$: features selected in every configuration are set as mandatory – not representable as BX;
- Optional features OF: selected features must exist in the feature model.

Multidirectional QVT-R Checking

- Extension of the bidirectional forall-there-exists quantifier patterns with a single target;
- One predicate for every model: for all elements in *all* source models, there exists at least one element in the target model.

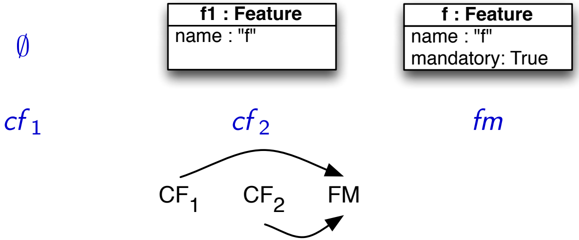
Multidirectional QVT-R Checking

```
top relation MF { n : String;
      domain cf1 s1 : Feature { name = n }
      domain cf2 s2 : Feature { name = n }
      domain fm  f  : Feature { name = n,
                                 mandatory = true } }
```



$MF_{\texttt{FM}}$ $MF_{\texttt{CF}_1}$ $MF_{\texttt{CF}_2}$

Multidirectional QVT-R Checking



$\emptyset$

f1 : Feature
name : "f"

f : Feature
name : "f"
mandatory: True

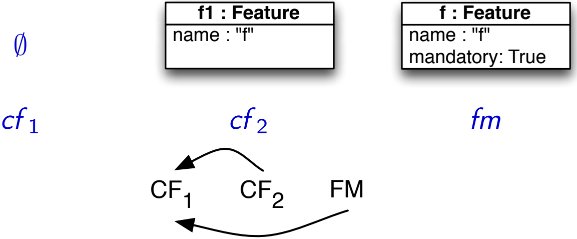
cf_1 cf_2 fm

CF_1 CF_2 FM

$$
\begin{aligned}
&\forall\, n : \texttt{String}, s_1 : \texttt{Feature}_{cf_1}, s_2 : \texttt{Feature}_{cf_2})\ |\\
&\quad n = s_1.\texttt{name} \wedge n = s_2.\texttt{name} \Rightarrow\\
&\qquad (\exists\, f : \texttt{Feature}_{fm} \mid n = f.\texttt{name} \wedge f \in \texttt{mandatory})
\end{aligned}
$$

- Desired behavior.

Multidirectional QVT-R Checking



$$\forall\ n : \texttt{String}, f : \texttt{Feature}_{fm}, s_2 : \texttt{Feature}_{cf_2} \mid$$
$$n = f.\texttt{name} \wedge n = s_2.\texttt{name} \wedge f \in \texttt{mandatory} \Rightarrow$$
$$(\exists\ s_1 : \texttt{Feature}_{cf_1} \mid n = s_1.\texttt{name})$$

- Trivially true: no extra conditions would fix it.

Relation Dependencies

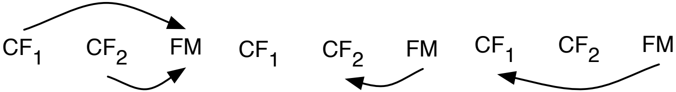
- No *fixed* combination of dependencies could specify the transformation intentions;
- *OF* is not representable: QVT-R does not support asymmetric relations;
- The model dependencies must be *customizable*;
- We propose an extension to handle these issues.

Relation Dependencies

- We introduce the notion of *consistency dependency*;
- $\{M_1, ..., M_2\} \rightarrow M_T,\ M_T \neq M_i$;
- A single target model depends on a set of source domains;
- Checking semantics runs a predicate for each dependency.

Example Revisited

- *MF* : $\{\mathtt{CF}_1\ \mathtt{CF}_2 \to \mathtt{FM}, \mathtt{FM} \to \mathtt{CF}_1, \mathtt{FM} \to \mathtt{CF}_2\}$



- *OF* : $\{\mathtt{CF}_1 \to \mathtt{FM}, \mathtt{CF}_2 \to \mathtt{FM}\}$
- Conservative extensions: standard semantics can be easily implemented.

Relation Invocations

- The direction of invocations should follow the direction of the current check;
- Each dependency predicate should invoke relations under the same dependency;
- May not exist: a relation R can be called by another S if the dependencies of R entail those of S.

Multidirectional QVT-R Enforcement

- The standard enforcement semantics also follow the forall-there-exists pattern;
- A single target model is generated from all the sources;
- $\overrightarrow{MF} : \mathtt{CF}_1 \times \mathtt{CF}_2 \rightarrow \mathtt{FM}$, $\overrightarrow{MF} : \mathtt{CF}_2 \times \mathtt{FM} \rightarrow \mathtt{CF}_1$, $\overrightarrow{MF} : \mathtt{CF}_1 \times \mathtt{FM} \rightarrow \mathtt{CF}_2$
- Too restrictive: consider the update of the feature model FM.

Enforcement Semantics

- In previous work we proposed enforcement semantics based on the principle of *least change*;
- Given a consistency relation and a model distance Δ, calculate the closest consistent model;
- This can be trivially adapted to the multidirectional scenario considering Δ is generalized;
- The transformation shapes are specified by different Δ;
- E.g., $\Delta_{\mathtt{CF}_1 \times \mathtt{CF}_2}$ gives rise to $\overrightarrow{MF} : \mathtt{FM} \rightarrow \mathtt{CF}_1 \times \mathtt{CF}_2$

Conclusions

- We have explored multidirectional transformations under QVT-R and shown that the language is too restrictive;
- We proposed an initial extension that allows the specification of interesting examples;
- Also improves expressiveness in the bidirectional scenario: allows the definition of asymmetric relations;
- Further work is required to test the expressiveness of the dependency language.