Logic-based reasoning support for Semantic Business Vocabulary and Rules

Dmitry Solomakhin  Alessandro Mosca  Enrico Franconi
presented by Rosella Gennari

Free University of Bozen-Bolzano, Italy
Piazza Domenicani 3, 39100 Bolzano, Italy

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Motivation: Business Models - Need for Automation

- Business models may explode in size and become incomprehensible, e.g. like in Magento eCommerce.

- The Semantics of Business Vocabulary and Business Rules standard allows to model rules using Structured English:

Each invoice includes at most one coupon.

It is obligatory that each coupon usage is validated.

- No existing modeling approach enables automated reasoning about business rules.
Semantics of Business Vocabulary and Business Rules (SBVR)

- Provides means for specifying business rules in natural language.
- Defines two types of business rules: structural and behavioural.
- Adopts ORM2 and CogNIAM graphical notations.
Merging business models (e.g. $A$ and $B$) may lead to conflicting rules:

$\left( R^A_1 \right)$ Each car rental is insured by exactly one credit card.

$\left( R^B_1 \right)$ Each luxury car rental is a car rental.

$\left( R^B_2 \right)$ It is obligatory that each luxury car rental is insured by at least two credit cards.
Problem

- Merging business models (e.g. $A$ and $B$) may lead to conflicting rules:
  
  $(R^A_1)$ Each car rental is insured by exactly one credit card.

  $(R^B_1)$ Each luxury car rental is a car rental.

  $(R^B_2)$ It is obligatory that each luxury car rental is insured by at least two credit cards.

- No underlying logical formalism — no SBVR reasoner.

- Our solution is to define a logical formalization of SBVR and provide a reasoning support on top of it.
Logic for Formalization of SBVR

- We introduce first-order deontic-alethic logic (FODAL) – multimodal predicate logic with complete and sound axiomatization.

- Fully captures the desired semantics of business rules:

$$(\tilde{R}_1^A) \quad \square (\forall x \exists^1 y (\text{CarRental}(x) \land \text{Insured}(x, y)))$$

$$(\tilde{R}_1^B) \quad \square (\forall x (\text{LuxuryCarRental}(x) \rightarrow \text{CarRental}(x)))$$

$$(\tilde{R}_2^B) \quad O (\forall x \exists^\geq 2 y (\text{LuxuryCarRental}(x) \land \text{Insured}(x, y)))$$

- Axiom allowing for interaction of modalities: \( \square(\phi(x)) \rightarrow O(\phi(x)) \).
Reasoning in FODAL

▶ Full FODAL (thus SBVR) is undecidable, so we concentrate on the fragment which is relevant in practice.

▶ The description logic fragment is a perfect candidate, since it also provides mechanisms facilitating translation into OWL2 ontologies.

▶ Our approach to reasoning is based on reducing the satisfiability in our fragment of FODAL to that of $\mathcal{ALCQT}$ description logic.
Automated Reasoning Support Tool

The functionality of the developed tool includes:

- Checking the consistency of a given set of business rules.
- Translating a set of necessity rules of a given ORM2 schema into OWL2 ontology.
Checking the consistency of a given set of rules

Halpin and Morgan, 2008, p.295

ENTITYTYPES: {A, B, C}
RELATIONS: {R, S}
TYPE(R.a, A)
TYPE(R.b, B)
TYPE(S.a, A)
TYPE(S.c, C)
LOC-ROLES-INDEX: {(R.a, 1), (R.b, 2), (S.a, 1), (S.c, 2)}
FREQ({S.a}, (1,3))
O-SETisa({C}, B)
MAND({R.a}, A)
MAND({S.a}, A)
\OB{ R-SETexc({R.a}, {S.a}, {(R.a, S.a)}) }
Checking the consistency of a given set of rules

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Conclusion

- The FODAL logic provides underlying formalism for the SBVR standard.

- Defined formalization enables automated reasoning support for a relevant fragment of SBVR.

- Translation to OWL2 ontologies facilitates interoperation between existing modeling approaches.
Future work

- Investigate decidable extensions of the $\mathcal{ALCQI}$-expressible fragment of SBVR.

- Elaborate further reasoning tasks for business rules (e.g. entailment).

- Inquire into approach of translating a full ORM2 schema with its alethic and deontic rules to SWRL or some other extension of OWL2.