Context-Sensitive Description Logics in a Dynamic Setting

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RoSI - TU Dresden
Role-based Software Infrastructures for continuous-context-sensitive Systems

Overview

Context-Sensitive DL in a Dynamic Setting

- Description Logics of Context
- Dynamic Setting

Contribution to RoSI

Context-Sensitive DL in a Dynamic Setting

Description Logics

- a **family** of formal knowledge representation languages
- decidable (most of them)
- feasible (most of the cases)

Syntax :

- N_C, N_R, N_I : concept, role, and individual names respectively
- a TBox $\mathcal{T}$: describes the hierarchy, relation between concepts
- a ABox $\mathcal{A}$: represents the data
- a RBox $\mathcal{R}$: desrcibes the role properties and hierarchy

Formal Descriptions - DL $\mathcal{SROIQ}$

Concept Expression

$$\mathbf{C} ::= N_{\mathbf{C}} \mid (\mathbf{C} \sqcap \mathbf{C}) \mid (\mathbf{C} \sqcup \mathbf{C}) \mid \neg\mathbf{C} \mid \top \mid \bot$$
$$\exists \mathbf{r}.\mathbf{C} \mid \forall \mathbf{r}.\mathbf{C} \mid \geq n\mathbf{r}.\mathbf{C} \mid \leq n\mathbf{r}.\mathbf{C} \mid \exists \mathbf{r}.Self \mid \{a\}$$

General Concept Inclusion (GCI) - TBox

$C \sqsubseteq D$.

$C \equiv D$ stands for $C \sqsubseteq D$ and $D \sqsubseteq C$.

Individual Assertions - ABox

$C(a)$, $r(a, b)$, $a \approx b$, or $a \not\approx b$

Role Inclusion - RBox

$s_1 \circ \ldots \circ s_n \sqsubseteq r$

ConDL

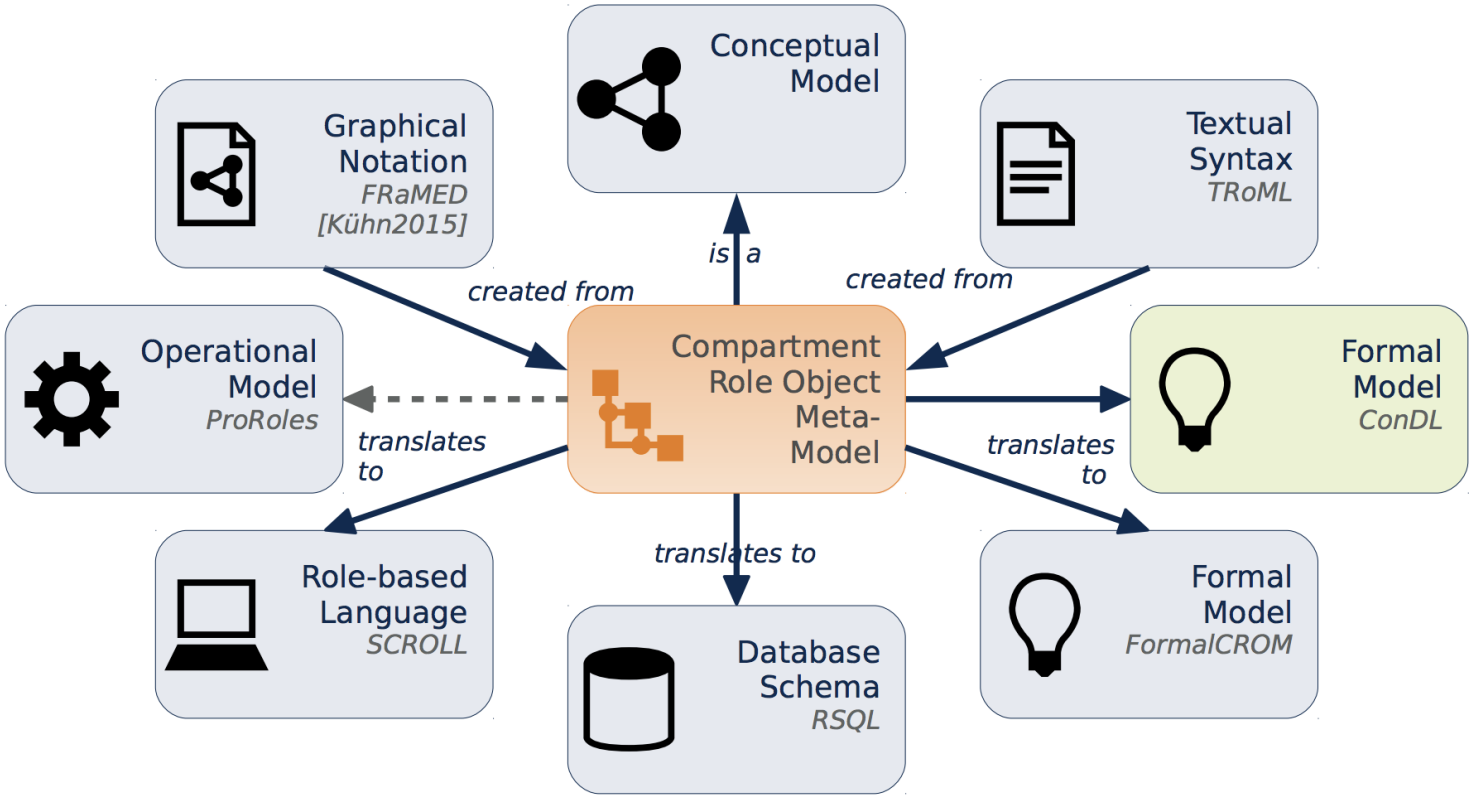

Figure 1: CROM - ConDL

https://wwwdb.inf.tu-dresden.de/grk/wp-content/uploads/2017/03/RoSI_Seminar_Thomas_Kuehn_2_270318.pdf

Two-dimensional context DLs $\mathcal{L}_m[\![\mathcal{L}_o]\!]$ [2]

Axiom Examples

$$\top \sqsubseteq [\![\exists worksFor.\{Siemens\} \sqsubseteq \exists hasAccessRights.\{Siemens\}]\!]$$

$$WORK \sqsubseteq [\![\exists worksFor.(Bob, Siemens)]\!]$$

ConDL

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Other considerations (e.g. rigid concepts and roles)

CROM to ConDL

DL - $\mathcal{SHOIQ}[\![\mathcal{SHOIQ}]\!]$ [3]

Verifying consistency of CROM models

- encode the CROM model to ConDL
- JConHT : a $\mathcal{SHOIQ}[\![\mathcal{SHOIQ}]\!]$ reasoner
- 2*EXPTIME*-hard

Dynamic Setting

Possible approach:

- situation calculus
- temporal logics
- non-monotonic logics

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How many layers do we need?

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Should we go deeper...?

https://suwalls.com/digital-art/recursive-painting-9137

A Step Back

What are the questions we want to answer?

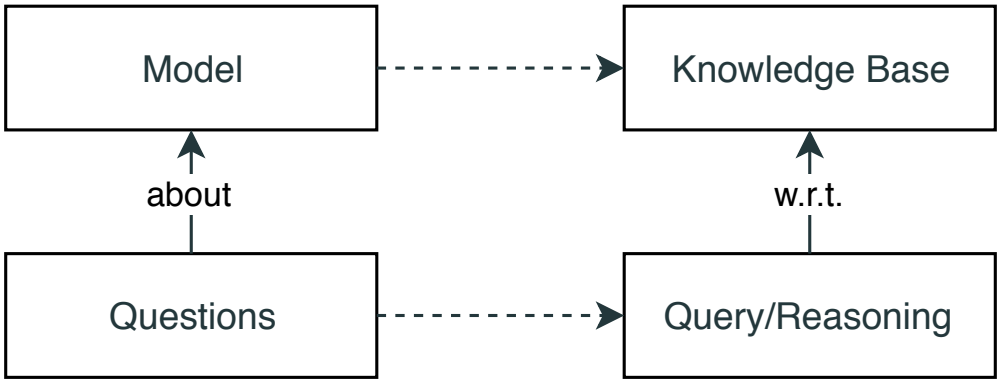

Figure 2: Knowledge Base System Schema

Situation Calculus

Used to describe a dynamic domain.

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FOL

- *actions* that can be performed in the world
- *fluents* that describe the state of the world
- *situations*

Situation Calculus

Used to describe a dynamic domain.

$$FOL \begin{cases} \bullet \ \textit{actions} \text{ that can be performed in the world} \\ \bullet \ \textit{fluents} \text{ that describe the state of the world} \\ \bullet \ \textit{situations} \end{cases}$$

A situation is :

- *init*, the initial situation, or
- $do(A, S)$, the situation resulting from doing action A in situation S, if it is possible to do action A in situation S.

Generally: undecidable

Situation calculus extended with DLs: undecidable [1]

Temporal Logics

Some examples (of LTL):

- $p \rightarrow q U r$: p implies q until r
- $\bigcirc p \rightarrow \bigcirc\bigcirc r$: if p holds at next step, r holds at two next steps

"Standard" temporal logics : decidable.

Contribution to RoSI

Real World Case - Chemical Reaction

Context-dependent:

- temperature
- catalyst
- surface area
- etc.

Some reactions are irreversible.

https://pixabay.com/en/chemical-reaction-experiment-flask-24562

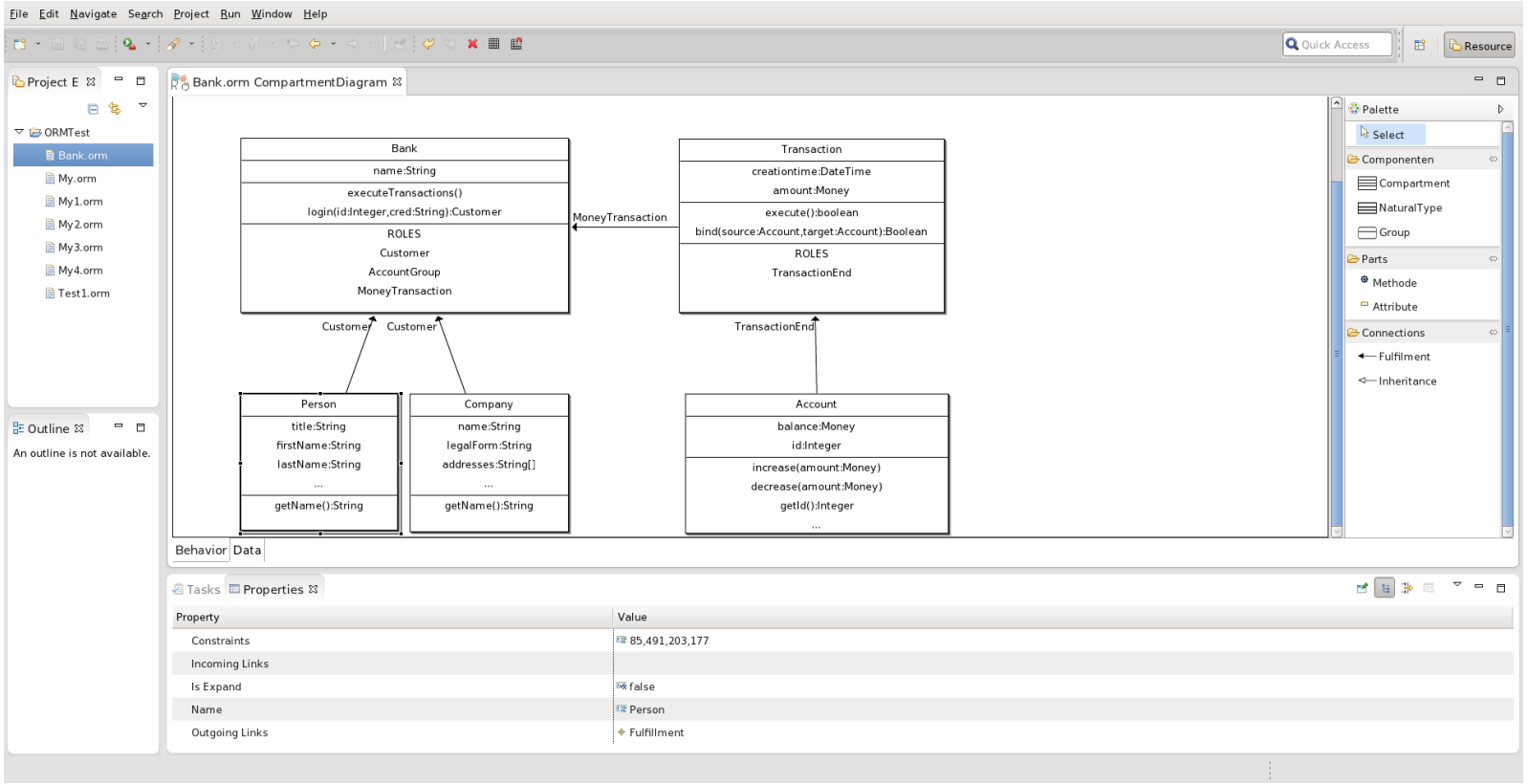
Real World Case - Security System

Some interesting questions :

- which combination of contexts that leads to unintended conclusion
- can we make sure a data is safe after an individual change the role?

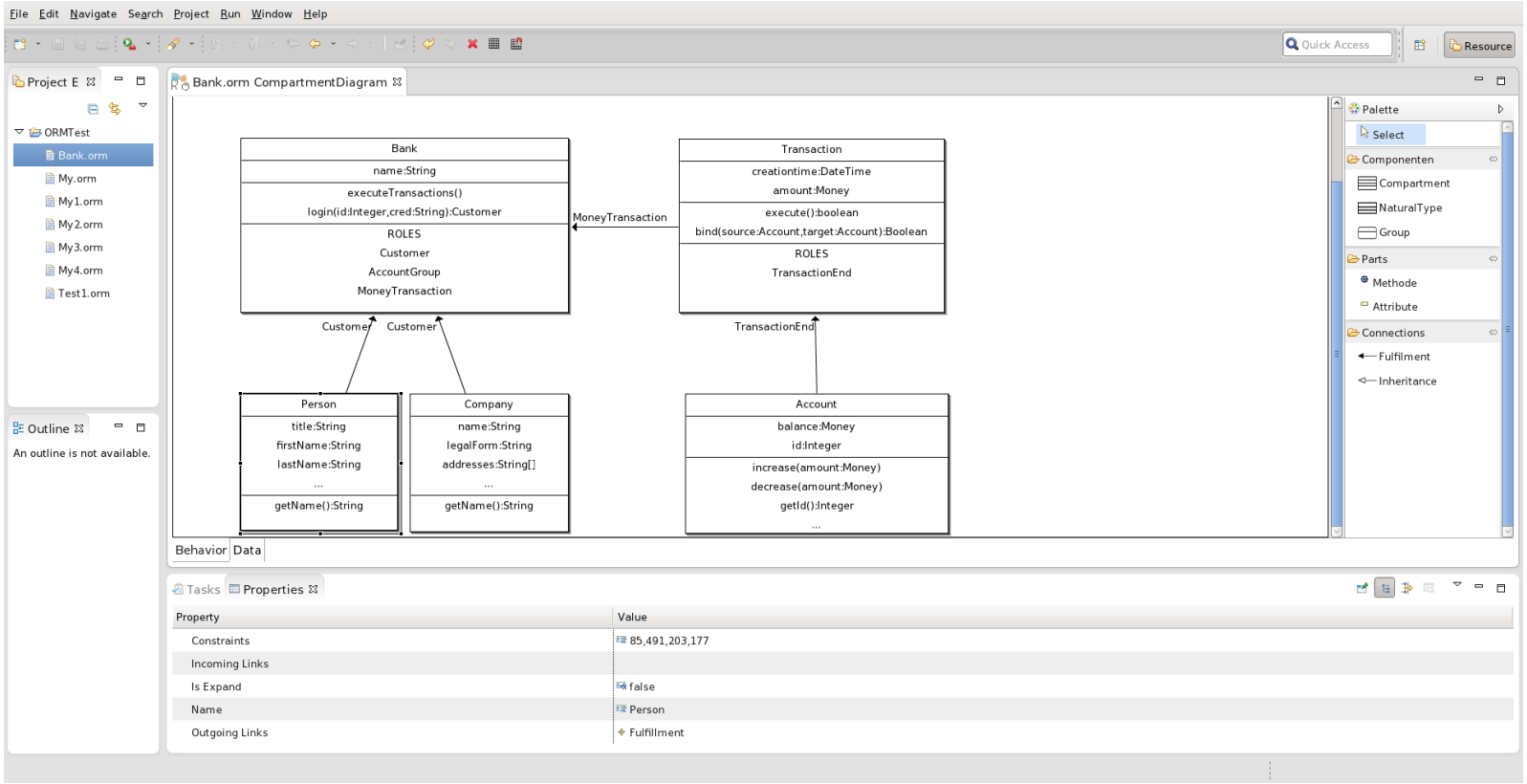
https://pixabay.com/en/cyber-security-encryption-security-2537786

About CROM



The formal model is static

About CROM



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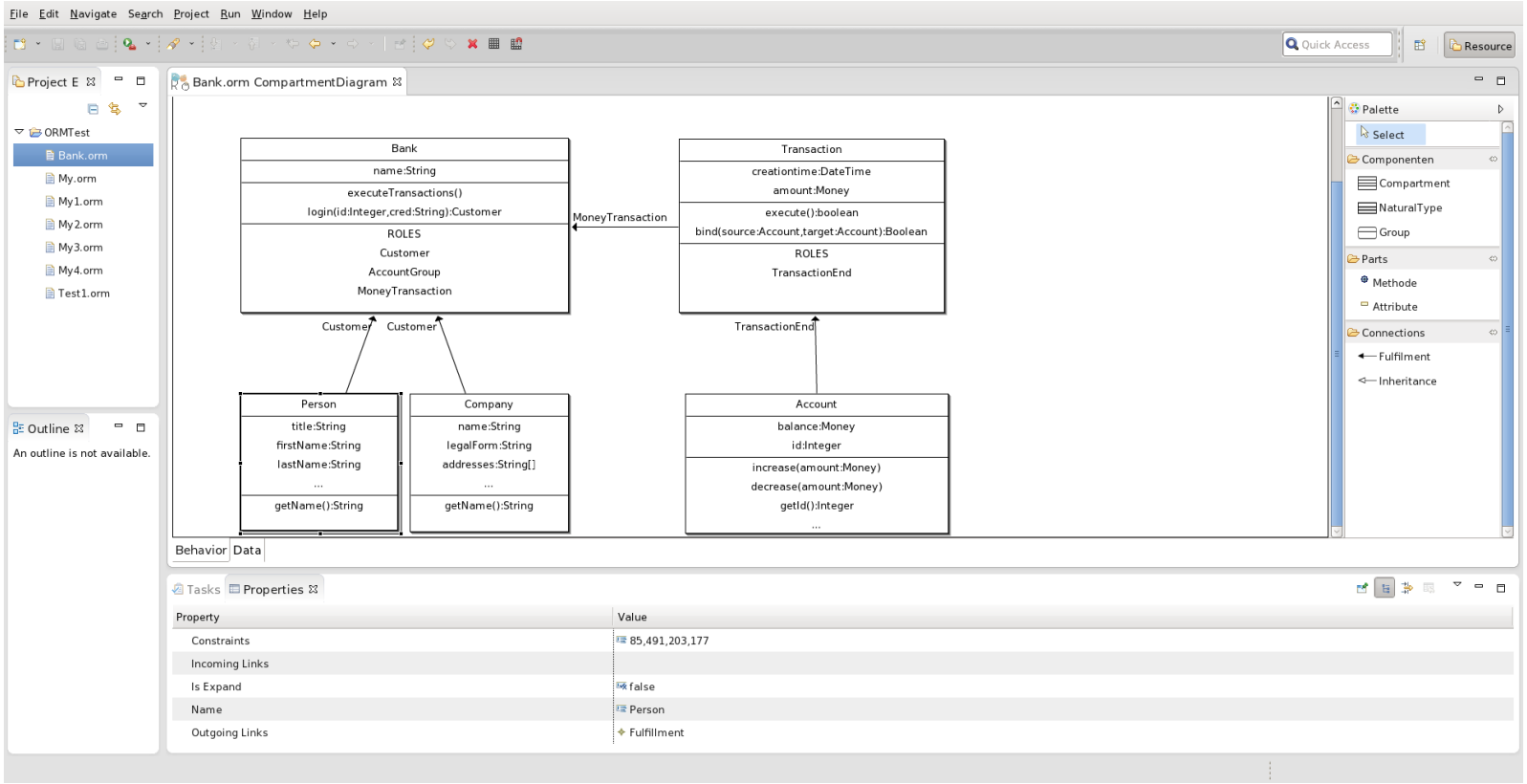

The formal model is static(?)

Thus, we need a dynamic language for CROM (e.g. event-based)

Questions?

Questions?

Idea?

Further Reading i

Calvanese, Diego and De Giacomo, Giuseppe and Soutchanski, Mikhail
On the undecidability of the situation calculus extended with description logic ontologies.
AAAI Press, 2015.

Böhme, Stephan and Lippmann, Marcel
Decidable description logics of context with rigid roles.
International Symposium on Frontiers of Combining Systems. Springer, Cham, 2015.

Böhme, Stephan and Kühn, Thomas
Reasoning on Context-Dependent Domain Models.
Joint International Semantic Technology Conference. Springer, Cham, 2017.

Further Reading ii

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Wolpertinger: A Fixed-Domain Reasoner
ISWC 2017 : Demo Track

Sarah Alice Gaggl, Sebastian Rudolph, and Lukas Schweizer.
Fixed-domain reasoning for description logics.
Proceedings of the 22nd European Conference on Artificial Intelligence (ECAI 2016), volume 285 of *Frontiers in Artificial Intelligence and Applications*. IOS Press, September 2016.