Combining Process and Ontological Modeling

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1 Introduction and Motivation

Recent development of information technology has significantly affected the way how an enterprize operate. Nowadays in corporate information systems not only process automation but also dealing with all stages of the business process lifecycle becomes increasingly important. Relevant tasks cover not only issues to be tackled on the design phase (e.g. process modeling, simulation, verification of different properties of a process, etc) but also problems arising in the phases of execution and analysis (such as process mining, monitoring, etc). All these tasks are the central issues of Business Process Management (BPM).

In order to enable automated reasoning support for processes along their entire lifecycle, several mathematical formalisms have been adopted to represent processes as formal models, including transition systems, process algebras and, finally, Petri nets. However, the well-known and avowed disadvantage of the family of these approaches, often referred to as process-centric, is that although they capture the workflow of the process itself, most of them abstract away from the semantics of data which a process might operate with. Nowadays such data is usually of a very complex structure due to the nature of information to be described (e.g. logistics, sales, etc.). Therefore, dealing with such data requires powerful tools even for static analysis. Moreover, in real life business processes usually require data integration because data may originate from heterogeneous sources. With respect to the importance of data integration many process modeling methodologies do not provide appropriate conceptual paradigms for specifying and enacting these kinds of tasks [7].

In response to such a drawback of traditional process-centric BPM techniques, a data-centric business modeling has recently emerged as a methodology in which processes are considered to be driven with the possible changes and evolutions of business data objects, called *artifacts*. This approach has become an area of growing interest, since it has been argued that considering data-centric perspective in business modeling can lead to substantial cost savings in the design and deployment of business processes [2].

Following the current trend of knowledge-aware business process modeling, in our research we address a problem of merging the process-related modeling techniques with ontological modeling and semantic technologies in general. The final goal would be providing a logical/formal framework which allows for modeling of business processes tightly coupled with the manipulated dynamic data, as well as for reasoning about and verification of different logical properties of such system. Such synthesis of models incorporating both a static and dynamic perspective, if exists, will require a very challenging task on defining algorithms for reasoning tasks, e.g. model checking, since in general that might lead to infinite-state models. Hence, not only new model checking algorithms have to be invented, but also decidable fragments of this combination should be investigated, mediating between relevance in practice and tractability [4].

2 The context of the research

The problems that are to be tackled along the research line can be considered relevant and useful in the context of the ACSI project [2], which is devoted to investigation on how the artifact-based approach may be used to optimize the business process management in the enterprize. The paradigm adopted there is presented in Figure 1 and consists of three layers: realization, artifact and semantics. The planned PhD research shares this paradigms and is supposed to focus on the semantic layer, i.e. to investigate the integration between the knowledge base describing the semantics of the data (ontologies) and high-level description of the business processes.

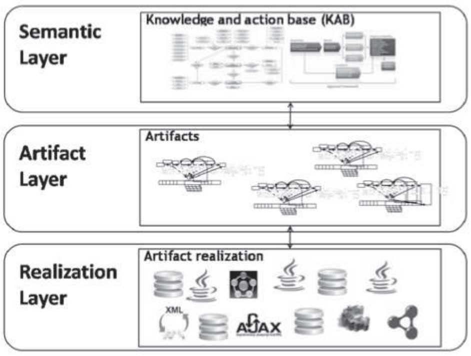

Fig. 1. ACSI Artifact Paradigm [2]

3 Current work

The recently introduced Guard-State-Milestone (GSM) artifact modeling language [6] provides means for specifying business artifacts lifecycles in a declarative manner, using intuitively natural constructs that correspond closely to how business-level stakeholders think about their business. The corresponding constructs are:

- *Information model* for modeling relevant data domain.
- *Milestones*, which naturally correspond to business operational objectives and are achieved based on triggering events and/or conditions over the information model.
- *Stages*, which correspond to clusters of activities intended to achieve milestones and which can have a hierarchical structure.
- *Guards*, which control when a stage can be activated.

As an example, let's consider a process $Func$ which is as simple as calculating a square root of a sum $\sqrt{a+b}$, given that $a \neq b$ and $a + b \geq 0$. The GSM concrete model of such process is represented on the Figure 2.

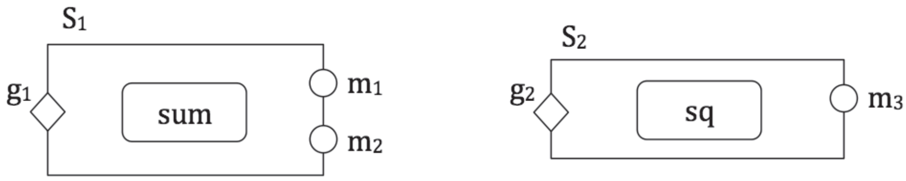

Fig. 2. GSM model of $\sqrt{a+b}$

Both milestones and guards are controlled in a declarative manner and corresponding definitions will have the following form:

$$\widetilde{g}_1 : \text{on } x.Func^{call}(a, b) \text{ if } a \neq b \qquad \widetilde{g}_2 : \text{on } +x.m_1$$
$$\widetilde{m}_1 : \text{on } x.Sum^{return}(c) \text{ if } c \geq 0 \qquad \widetilde{m}_2 : \text{if } c < 0$$
$$\widetilde{m}_3 : \text{on } x.Sq^{return}(d)$$

Despite having a formally specified operational semantics for GSM models [3], the verification of different properties of such models (e.g. existence of complete execution, safety properties) is still an open problem. In order to solve this problem, one should define a particular formalism that captures the intended operational semantics of the business artifacts and provides mechanisms to solve different verification tasks.

One of the most promising candidates for such a formalism is a data-centric dynamic system (DCDS) together with its general verification framework presented in [5]. A DCDS is a pair $\mathcal{S} = \langle \mathcal{D}, \mathcal{P} \rangle$, where $\mathcal{D}$ is a data layer and $\mathcal{P}$ is a process layer over the former.

The data layer $\mathcal{D}$ models the relevant database schema together with its set of integrity constraints, while the process layer $\mathcal{P}$ is a tuple $\mathcal{P} = \langle \mathcal{F}, \mathcal{A}, \varrho \rangle$, where

- $\mathcal{F}$ is a finite set of functions representing interfaces to external services.

- $\mathcal{A}$ is a set of actions of the specific form:

  $\alpha(p_1, ..., p_n) : \{e_1, ..., e_m\}$, where $p_1, ..., p_n$ are input parameters of an action and $e_i = q_i^+ \wedge Q_i^- \rightsquigarrow E_i$ are effects of an action of a particular form.

- ϱ is a process which is a finite set of condition-action rules of the form $Q \mapsto \alpha$, where α is an action and Q is a FO query over $\mathcal{R}$.

The decidability problem in the context of data-centric dynamic systems is one of the main challenges being investigated at the moment. However, unlike GSM, which has emerged to satisfy practical needs, DCDS benefits from having purely formal foundations, which provide instruments to approach and solve the challenge. Several decidability results have been obtained by Calvanese et. al [1] during their ongoing research. Therefore, it becomes of a particular interest to investigate the possibility to transfer these decidability results on GSM models.

Having a formal definition of an artifact and its lifecycle as a GSM concrete model, we aim to define a mapping which maps the artifact's relational schema into the data layer of DCDS and the set of ECA-like rules describing its behavior into the set of condition-action rules of the process layer of DCDS, where service calls are modeled by a finite set of functions $\mathcal{F}$.

Along the process of constructing the mapping we need to insure that the resulting DCDS model mimics the operational semantics of the initial GSM model. In particular, one would want to preserve the semantics of so-called B-Steps, which focus on what happens to a snapshot (i.e., description of all relevant aspects of a GSM system at a given moment of time) when a single incoming event is incorporated into it. In order to capture the semantics of B-Steps, we construct a so-called *conditional dependency graph*, which is then used to enforce the shape of the resulting condition-action rules in such a way that the final DCDS formalization may be, in fact, considered as an execution engine for the initial GSM model.

For example, assume a stage s_j and some guard $g_j^e = \textbf{on}\ \xi(x)\ \textbf{if}\ \phi(x)$ which opens the stage. Then activating the stage by validating g_j^e can be modeled by the following condition-action rule:

$$\begin{aligned}
&\exists \overline{a}, \overline{s}, \overline{m}\ R_{att}(x, \overline{a}, \overline{s}, \overline{m}) \wedge s_j = false \wedge R_{Blocked}(x, false) \mapsto \\
&\quad \alpha^{Activate}_{M,s_j}(id_R, a'_1, ..., a'_m) : \{ \\
&\quad R_{att}(id_R, \overline{a}, \overline{s}, \overline{m}) \rightsquigarrow R_{att}(id_R, \overline{a}, \overline{s}, \overline{m})[s_j/true, a_1/f^M(1), ..., a_k/f^M(k)] \\
&\quad R_{att}(id_R, \overline{a}, \overline{s}, \overline{m}) \rightsquigarrow R_M(id_R, f^M(1), ..., f^M(k)) \\
&\quad R_{att}(id_R, \overline{a}, \overline{s}, \overline{m}) \rightsquigarrow R_{Block}(id_R, true) \\
&\quad R_{att}(x, \overline{a}, \overline{s}, \overline{m}) \rightsquigarrow R^{StateChanged}_{s_j}(x, true)\}
\end{aligned}$$

4 Future work and concluding remarks

The results of the ongoing research are at the moment considered to be preliminary and subject to further investigation. In particular, one of the main future tasks is verifying that the introduced translation from GSM model specification into DCDS specification is consistent with respect to a certain family of the process properties. This is going to be done by attempting to define a bisimulation relation between two transition systems, inferred by the semantics of GSM and DCDS respectively. Another task is devoted to investigating the possibility to transfer the existing decidability results for DCDS [1] to GSM and to determine expressivity restrictions corresponding to those defined for DCDS.

Other future tasks in the context of the ACSI project include: a) determining the use cases for the semantic layer in the ACSI Artifact paradigm, which tasks can be (or should be) dealt with on this layer; b) attempting to define a "semantic concrete model" which would be an "implementation" of a semantic layer of the ACSI Artifact Abstract Model, or more specifically, how to complement a GSM Concrete Model with some notion representing the semantic layer.

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