An Event-B framework for the validation of Event-B refinement plugins (ongoing work)

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Abstract. We propose an Event-B framework for modeling the underlying theoretical foundations of Event-B. The aim of this framework is to reuse, for Event-B itself, the refinement development process. This framework introduces first, a functional kernel through an Event-B context, then, it defines Event-B projects, their static and dynamic semantics through Event-B machines. We intend to use this framework for the validation of Event-B plugins related to distribution and for Event-B extensions related to composition and decomposition.

1 Introduction

Event-B [2] is a method that has been proposed for building formal models together with their proofs. As a matter of fact, it has been used for a large range of applications. Nevertheless, it seems that, in general, it has not been applied to the field of software engineering by itself. In this paper, we report on an Event-B meta-framework and two software engineering applications for which the use of the Event-B methodology seemed to us worth to apply.

The rest of the paper is organized as follows. Section 2 outlines the main features of an Event-B framework. Section 3 discusses about two software applications. In conclusion, Section 4 considers some related work and sketch future work directions.

2 Towards an Event-B meta-level framework

The proposed meta-level framework aims at validating Event-B model transformations. We focus on transformations linked to a top-down, refinement-based development process. Their goal is to assist the user in producing refinements of his model through patterns parameterized with the help of domain specific languages. Thus, a transformation pattern takes as input an Event-B machine and some parameters. It produces either a single machine or a set of machines. In the latter case, it is necessary to model the project level – not a single machine – in order to consider the interaction of the machines of the project. However, to make things simpler, we consider neither contexts, nor refinement links between machines. Refinement will be taken into account at the meta level, each transformation producing a refinement of the project.

2.1 Methodology

We now propose a meta-level specification of an Event-B project in Event-B itself. The difficulty of such an exercise is to find the right level of abstraction and to identify which features should be modeled as constants and as variables. It is strongly linked with the objectives we have fixed. First, given the patterns we envision, predicates and expressions should be left as abstract as possible. Second, we target operations which should modify the project by adding new machines. Two orthogonal dynamics will thus be considered: project contents evolution and project operational semantics. Furthermore, we try to use a refinement-based approach to specify the meta-level: its features will be introduced incrementally.
2.2 The global view

Figure 1 describes the overall structure of a machine as a class diagram. The conversion to Event-B is performed as follows:

- **Machine** is introduced as a set, with **Machines** being the subset of existing machines.
- Machine attributes and operations can be updated and are defined as variables.
- **Predicate**, **Ident** and **EventName**. **Ident** is partitioned into **Var**, **Prime** denoting primed versions of machine variables and **Param**.
- **Event** is modeled as a triple with three projections (**Pars**, **Guard** and **Action**).

![Fig. 1. Event-B machines](image)

2.3 The functional kernel

The functional kernel introduces abstraction of predicates and events as Event-B contexts. A predicate is defined as a set of abstract states. It is mainly characterized by axioms stating the existence of the **Free** function returning the set of the free variables of a predicate and the substitution function. With respect to our specific needs concerning decomposition/composition and distribution we also assume the existence of a **Conjuncts** function returning a set of predicates of which conjunct is equivalent to the initial predicate. For instance, the conjuncts of “p = TRUE” is “{ p = TRUE }” and the conjuncts of “p = TRUE ∧ v = 2” is “{ p = TRUE, v = 2 }”. An excerpt of of the Predicate context is the following:

```plaintext
context cPredicate extends cIdent
```
sets State

constants Predicate Free Subst Proj Conjuncts ...

axioms
  @Predicate_def Predicate = P(State)
  @Free_ty Free ∈ Predicate → P(Ident)
  @Subst_ty Subst ∈ (Ident → Ident) → (Predicate → Predicate)
  @Proj_ty Proj ∈ P(Ident) → (Predicate → Predicate)
  @Conjuncts_ty Conjuncts ∈ Predicate → P1(Predicate)
  @Conjuncts_ax ∀ p · p ∈ Predicate ⇒ inter(Conjuncts(p)) = p
  @Free_Conjuncts ∀ p · p ∈ Predicate ⇒ union(Free[Conjuncts(p)]) = Free(p)
  ...

2.4 The Event-B project structure

Besides contexts, Event-B projects are modelled through the following refinement steps:

- **mProject** defines the overall structure of machines and a project as a set of machines and provides an event to add a machine to a project.
- **static_semantics** adds wellformedness rules concerning the usage of identifiers within predicates. Machine addition is restricted to well formed machines.
- **dynamics** adds the invariant preservation property and provides a dynamic semantics to a project through the introduction of a state and of the **step** event defining the operational semantics of the project.

2.5 Event-B project and machines

An Event-B project is seen as a set of machines. Each machine has variables, an invariant and a set of events indexed by event names. In order to make easier the meta-level reasoning, we consider that a machine has a unique invariant and that an event has a unique guard and a unique action (seen as a before-after predicate). These predicates will be seen as conjunctive later.

machine mProject sees cMachine cEvent

variables Machines mVars mInv mEvents

invariants
  @machines_ty Machines ⊆ Machine
  @mVars_ty mVars ∈ Machines → P(Var)
  @mEvents_ty mEvents ∈ Machines → (EventName → Event)
  @mInvns_ty mInv ∈ Machines → Predicate

events
  ...
end

The **mProject** machine also provides the **new_machine** event for adding machines to a project. Its takes seven parameters specifying the set of machines to be added and for each of them a set of variables, an invariant, event names, and parameters, guard and action of each event.
2.6 The static semantics

The static semantics specifies visibility constraints for variables and parameters:

- an invariant of a machine uses variables of this machine
- a guard of an event can use parameters of this event and variables of the machine the event belongs to.
- an action of an event can use parameters of this event, variables of the machine and their primed versions.

```plaintext
machine static_semantics refines mProject
sees cMachine

variables Machines mVars mInv mEvents

invariants
@Inv_ctr ∀ m · m ∈ Machines ⇒ Free(mInv(m)) ⊆ mVars(m)
@Guards_ctr ∀ m,e · m ∈ Machines ∧ e ∈ dom(mEvents(m)) ⇒ Free((mEvents(m);Guard)(e)) ⊆ mVars(m) ∪ (mEvents(m);Pars)(e)
@Actions_ctr ∀ m,e · m ∈ Machines ∧ e ∈ dom(mEvents(m)) ⇒ Free((mEvents(m);Action)(e)) ⊆ mVars(m) ∪ Next[mVars(m)] ∪ (mEvents(m);Pars)(e)
```

2.7 The dynamic semantics

This refinement takes into account the dynamic of a project. First, standard proof obligations are added to express that the machine invariant is preserved by each event. The expression of proof obligations takes advantage of the representation of a predicate as a set: conjunction and implication are replaced by intersection and set inclusion. Second the operational semantics of a project is defined through the introduction of a state for the subset of machines considered to be active, and a step event modelling the evolution of the state. The state is declared as a decomposable predicate over machine variables. It abstracts the usual view of a state as a valuation of each state variable. Machine invariants should be satisfied by the state.

```plaintext
machine dynamics refines static_semantics
sees cMachine cEvent

variables Machines mVars mInv mEvents state

invariants
@ts state ∈ Machines ⇒ Decomposable // only defined on active machines
@state_dync ∀m · m ∈ dom(state) ⇒ state(m) ⊆ mInv(m)
@free_state ∀m · m ∈ dom(state) ⇒ Free(state(m)) ⊆ mVars(m)
@mInv ∀m,e · m ∈ Machines ∧ e ∈ dom(mEvents(m)) ⇒ mInv(m) ∩ (mEvents(m);Guard)(e) ∩ (mEvents(m);Action)(e) ⊆ Subst(Next)(mInv(m))
```

The step event makes a machine of the project advance by updating its state. It takes as parameters a machine m, an event name e, a predicate p specifying the value of the parameters. The event guards are supposed to be satisfied by the current state of the machine. Then its state is updated by applying the

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1 For the moment, we do not take into account refinements and consequently the gluing invariant.
machine action. The new state is obtained by suppressing primed in the projection on primed variables of the conjunction of the old state, the parameters and action predicates.

```
  event step
  any m e p
  where
    @m_ty m ∈ dom(state)
    @e_ty e ∈ dom(mEvents(m))
    @p p ∈ Predicate
    @f Free(p) ⊆ Param
    @g state(m) ∩ p ⊆ (mEvents(m);Guard)(e)
  then
    @a state(m) := Subst(Next∼)(Proj(Next[mVars(m)])(state(m) ∩ p ∩ (mEvents(m);Action)(e)))
end
```

We also introduce an event to change the active set of machines: some old machines can be replaced by new machines taken in the pool of currently inactive machines. This event can be seen as a hot replacement of components. It should be transparent. For this purpose, we suppose that the conjunction of old machine states is equal to the conjunction of new machine states. A typical application will be to replace a compound machine by its subcomponents once it has been split.

3 Case studies

We have experimented the above meta description on two Event-B model transformations. The first transformation deals with a safe refinement development process for distributed applications [8]. This development process proposes successive steps for splitting and scheduling complex events. These steps are defined by refinement patterns. They are specified through domain specific languages. From these specifications, two refinements were generated. In the first phase of this work, the generated refinements had to be verified through the Event-B framework, i.e., the Rodin verification platform. With respect to that work, our motivation was to assert that the application of the proposed patterns actually produce refinements of the source machine, so that the generated machines are correct by construction. Thus, it should not be necessary to validate these refinements for each application of the corresponding pattern. The second transformation deals with Event-B by itself. Actually, the last developments of Event-B propose to enhance Event-B by decomposition methods. This has lead to two proposals: the state-based [5] and the event-based [9]. Both methods have strong theoretical foundations. Moreover, they have been validated by significant applications and have been both implemented by plugins available through the Rodin platform [10]. With respect to these studies, our second motivation was how to manage the theoretical background that is required for the justification of Event-B enhancements like decomposition methods.

4 Related Work and Conclusion

It is interesting to cite related works which have some connections with ours. First, Iliasov et al. [7] is a pioneering work for dealing with the automation of development steps. For this purpose, they propose the notion of refinement patterns. Such refinement patterns contain a syntactic description, applicability conditions and proof obligations ensuring correctness preservation. Unlike our approach where we stayed within an Event-B world, [7] adopt specific languages for representing Event-B models and their so-called transformation rules. Last, the reuse of the Event-B proof engine is not immediate. Also, Cataño et al. [3] adopt the so-called own medicine approach in the sense that they adopt Event-B for formalizing Event-B and JML and the Rodin platform to discharge their proof obligations. With respect to that our work is
similar. However, their model is mainly functional and their transformations are defined as functions. Their correctness is stated through theorems. With respect to Event-B, we have gone further since we have adopted a state-based approach. The dynamic semantics as well as model transformations are defined as events. The correctness of the dynamic semantics and of the transformations are obtained for free through the Event-B refinement. Moreover, Cataño et al. [3] are concerned neither by the validation of refinement patterns nor by the semantics of composition.

To conclude, Event-B proposes a refinement-based development method. In this paper, we have studied how to support such a development method by itself in order to formalize the underlying theoretical background: the so-called meta level. The elaborated framework can also be used to support Event-B enhancements as composition and decomposition methods. As future work, we envision to broaden the coverage of our framework. We are also interested in formalizing the links between Event-B and temporal or temporized logics. More generally, the explicit description of dynamic behaviours through temporized patterns within an Event-B framework looks challenging.

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