Correctness of automatically generated choreography specifications*

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Abstract. The service choreography approach has been proposed for the declarative specification of multi-party conversations between participant services, in service-oriented applications and web transactions. Constraint solvers such as Alloy Analyzer can be used for the automated generation and verification of declarative choreography specifications. This presumes a mapping between the declarative specification of business rules in *Semantics of Business Vocabulary and Rules* (SBVR), an OMG standard for specifying business models in structured English, and the *Alloy Analyzer* which is a SAT based constraint solver. This paper is concerned with the correctness of such mapping between the generated instance (choreography) in Alloy and the global graph obtained as a direct visual representation of the SBVR model specification.

Keywords: declarative specification · service choreography · SBVR · constraints · model transformation · mapping correctness

1 Introduction

The service choreography approach [37] coordinates the collaboration of distributed systems across autonomous participant services [33]. Choreography focuses mainly on prescribing the ordering of the message exchange between services, according to agreed global constraints. It is key to realising value added service chains in ecosystem oriented architectures [19].

The OMG standard *Semantics of Business Vocabulary and Rules* (SBVR) [30] intends to express complex business requirements declaratively. Recent works [5,15,1,17] advocate SBVR for specifying business models. They tend to capitalise on the fact SBVR specifies rules in natural language, which the end-user to validate the specification directly, and at the same time describes them in formal logic, which is beneficial for verification.

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In previous work, we have applied SBVR and its supplement, the *Date-Time Vocabulary* (DTV) [32], for specifying service choreographies [1,17]. An application to commuter journeys was given in [14]. Further, the *SBVR2Alloy* compilation tool [16] has been built that can automatically generate the service choreography, corresponding to the input SBVR model. An Alloy model [1] describes a set of constraints in terms of structure. It generates an analysis automatically and produces an instance structure of model that satisfies the ordering of constraints in a service choreography.

In addition to verifying conformance to message ordering constraints, the *Alloy Analyzer* constraint solver [13] can be used to perform realisability checks and assert static constraints on the generated choreography.

In this paper, the focus is on the correctness of the mapping between the input SBVR model capturing the business rules and the Alloy model[13] used to generate the corresponding choreography, and verify for realisability.

The main contribution of this paper is a method for checking the correctness of the mapping between (a) the model transformation from SBVR into Alloy [16], and (b) the generated global view [9,36,4] which is a visual representation translating from the corresponding SBVR model. Both models describe the global behaviours and the complex interactions in the choreography specification.

This paper is laid out as follows. Section 2 introduces basic handling of constraints in SBVR as well as the mapping of the SBVR model onto the Alloy model. Section 3 describes the semantics of the global view represented in the visual representation, and shows how the mechanism applies for transforming the SBVR model into the global view, and the correctness of the conformance mapping. Section 4 discusses related work and Section 5 contains some conclusions and future work.

2 Mapping an SBVR model onto an Alloy Model

In this section, a brief introduction to the OMG standard SBVR is provided and the development of an SBVR model is outlined. We then describe how the SBVR model is mapped onto the Alloy Model, using *Alloy Analyzer*.

2.1 An OMG standard SBVR

The OMG standard SBVR [30] provides a means to express business concepts and rules in natural language for different types of business activities. SBVR rules are expressed in Structured English (SBVR - SE) [30] which is formed by means of semantic formulations. The SBVR rules describe the meaning of business rules by composing the logical formulation which is in the form of the combination of atomic formulation (e.g., Fact Types), modality (i.e., obligation, prohibition, etc), logical operation (i.e., OR, XOR, AND, etc), and the quantification (e.g., exactly one, at least one, etc). This combination produces a constructive rule, e.g., *It is obligatory that each rental car is owned by at least one branch.* The deontic modality, i.e., 'obligatory' on the constraint defined by the rule. The quantification, 'each' and 'at least one' effect restriction of the rental car belonging. Furthermore, 'is owned by' is the designation for the Fact Type which makes an assertion on the corresponding Terms (rental car and branch).

2.2 SBVR model for service Choreography

The SBVR model prescribes a set of global constraints from informal requirements, namely an agreed contract of common rules that govern the allowed interactions and the ordering of services interaction. The structure of the rules is based on the semantic formulations that are used in the SBVR standard [30] and supplemented by the DTV [32].

Figure 1 represents the overall picture of how an SBVR model is built for service choreography. A set of terms and a set of fact types in SBVR is essential for constructing the rules. Then two main components, participants and events, play an important role in modelling choreography. Each designated participant involved in the multi-party conversation (i.e. participant), each designated event characterises the occurrence of event (messages exchange) performed by the participant(s) (i.e. event), and static constraints specify the domain specific constraints for each participant and event, are defined as Term, e.g. **Term:** participant 1, **Term:** participant 2, **Term:** event 1, **Term:** static 1 as shown in the figure.

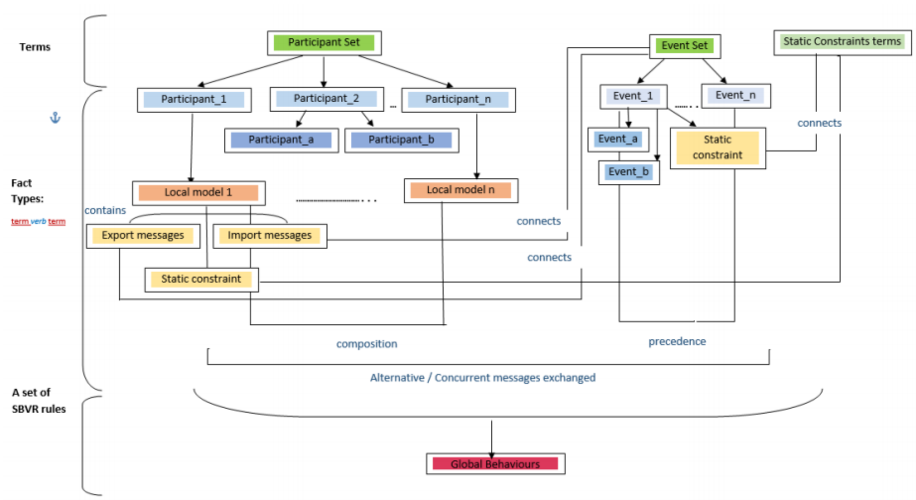

Fig. 1: Coordinating SBVR model for service choreography

The Fact Types (FT) of the SBVR model for specifying the participant set (e.g. **FT:** participant2 includes participant) and the event set (e.g. **FT:** event1 includes event) applied Set Definition in SBVR standard. On the other hand, "term verb term" has been used to specify the static constraints and the messages exchange including the export and the import messages. It is important to represent the local behaviour of each participant.

These SBVR rules capture the specification of the ordering of services interaction where the time notion of precedence, 'immediately precedes', by DTV [32], is advocated. Differently, the SBVR rules for specifying the complex interactions: concurrent and alternatives interactions apply the logical operators (AND, XOR, and OR) in the SBVR standard. The interested reader might refer [1,16] for further explanation.

2.3 Mapping the SBVR model into the Alloy model

Alloy analyzer is based on a logic which provides the structures representing relations. Alloy model consists of a module containing a number of signatures and abstract signatures. Signatures represent terms, while abstract signatures describe the participant set and the event set in the SBVR model. Table 1 shows participant1 is a member of the participant. Furthermore, Rule 1 illustrates a nesting of event1. Each signature and abstract signature introduce fields which are captured by relations. These fields denote *verb* interconnecting with Terms in each FT. It is used to specify the import and the export messages by/from the participant(s) (see Table 1).

The multiplicities in Alloy are applied to illustrating the accurate meaning of the complex interactions as well as the ordering of messages exchanged in the choreography. The combination of signature, multiplicities, and field are the basis of the development of SBVR rule in Alloy. In addition, facts and predicates in Alloy are deployed to constrain a certain case.

Rule 1 represents the general form of rule capturing the alternative interaction concerns on the sending (receiving) of the choices of events which is emphasised by specifying the logical operation **or ... but not all**. In Alloy, fact is exploited to ensure the explicit choices is defined (only one of the events will be true). Lone multiplicity (it can be true or false) is declared for each subsignature of event 1. Fact is applied for translating Rule 2 too. Rule 2 constrains at least one of the events is selected by the participant1. Rule specifies the alternative interaction encapsulates inclusive choices (OR) of the events. Hence, lone multiplicities instead of one multiplicity associated on event 1 and event 2 are mapped from each corresponding verbs 1 and verbs 2 that connect with the signature participant1.

Rules 3 - 4 specify the allowed orderings of the messages exchange when the multi-party conversation takes place. Rule 3 demonstrates there is no occurrence of an event after event 1 and before event 2. A notion of *immediately precedes* definition is advocated from DTV [32]. Rule is translated into Alloy by defining a signature of the initial event which is mapped to the field 'immediatelyprecedes' associating with the event occurs immediate after.

In modelling services interaction, there is the case when no indication to inform which interaction is performed initially as in the FTs specification: participant1 sends event1; participant2 receives event1. As the solution, the principal concept

Table 1: Mapping of SBVR2Alloy model

SBVR model	Alloy model
Terms Term:participant1; Term:event1; Term:static1; Term:T1;	**signature** sig participant1{}; sig event1{}; sig static1{}; sig T1{};
FT : participant and event set Fact Type: participant *includes* participant1; Fact Type: event *includes* event1;	**abstract signature** abstract sig participant{} one sig participant1 extends participant{} abstract sig event{} one sig event1 extends event{}
FT : messages exchange and static constraint Fact Type: participant1 *verbs* event1 Fact Type: participant1 *verbs1* static1	**field (relation)** one sig participant1 extends participant{verbs1: one event1, verbs: one static1}
Rules : complex interaction Rule 1: It is obligatory that the participant1 *verbs* exactly one event1 that *includes* exactly one eventa **or** exactly one eventb **but not both** at exactly one T	**field (relation), fact, and multiplicities** one sig participant1 extends participant{verbs: one event1} abstract sig event1 extends event {at: one t1_event1} {(event1 = eventa and no eventb) or (event1 = eventb and no eventa)} lone sig eventa extends event1{} lone sig eventb extends {}
Rule 2: It is obligatory that the participant1 *verbs* exactly one event1 **or** exactly one event2, at exactly one T	one sig participant1 extends participant{verbs1: lone event1, verbs2: lone event2} { verbs1 = 1 or verbs2 = 1} lone sig event1 extends event {at: one t1_event1} lone sig event2 extends event {at: one t1_event2}
Rules : the ordering of messages exchange (events) Rule 4: : It is obligatory that exactly one event1 *immediately precedes* exactly one event2 Rule 6: It is obligatory that exactly one T1 *immediately precedes* exactly one T2	**field (relation), fact, and multiplicities** one sig event1 extends event {immediatelyprecedes: one event2 one sig T1 extends Time {immediatelyprecedes: one T2}

in the DTV, a notion of time understood as in the construct occurrence at time interval is applied. Hence the following time declarations as well as Rule 4 are used. 1. participant1 sends event1 at T1; 2. participant2 receives event1 at T2. The same mechanism for translating Rule 4 and Rule 5 is applied for transforming Rule 6 into Alloy.

3 Correctness of SBVR2Alloy model

In this section, we outline the main aspects for ensuring the correctness of the mapping, which draws upon the semantics of global view.

3.1 Global view of choreography

The semantics of global view of choreography [36], which is given as a visual representation (graph), is proposed for checking the correctness of the mapping between the SBVR model and Alloy model, built in Alloy Analyzer. Our interest in this approach is on its visual representation and its compatibility with our choreography model, characterising the behaviour from the specifications to capture the complex interactions in the business model.

The coordination of services interaction between participants in global view is modelled with representing the interactions between the participant 1 and the participant 2 who is sending and receiving message, m, respectively. This interaction denoted by $P1 \rightarrow$ P2:m .

A *global choreography (g-choreography)* denoted by G is derived by the semantics: i. $G ::= 0$ (no interaction); ii. $p_1 \rightarrow \mathrm{p}_2 : m$ (a simple interaction between two participants p_1 and p_2); iii. $G; G'$ (sequential of two g-choreographies) iv. $G|G'$ (parallel between two Gs) v. $G+G'$ (choices of Gs). This can be illustrated respectively in the following figure. Each graph in Figure 2, ○ represents the initial state, ◎ represents the final state, while ◇+ depicts the alternative interaction in the branching graph and □| represents the concurrent interaction in the parallel graph.

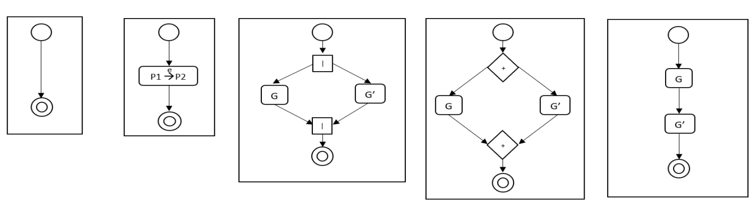

Fig. 2: Global view graph as a visual representation

As discussed previously, an SBVR model consists of several rules specifying the complex interactions involved in the choreography. To build a global view, the following SBVR rules are considered as an illustrative example of the specification to show a single interaction between participant 1 and participant 2 (Rule 1 and Rule 2), subsequently participant 2 and participant 3 (Rule 3 and Rule 4), and the ordering of both interactions (Rule 5). Verbs associated with the event and particularly with T1 in the rule, illustrate the intended participant will be sending the event, conversely, verbs associated with the event which is mapped with T2, specify the intended participant will be receiving the event. In real, verb can be any vocabularies representing the same meaning of sending and receiving.

Rule 1: It is obligatory that the participant 1 verb1 exactly one event 1 at exactly one T1
Rule 2: It is obligatory that the participant 2 verb2 exactly one event 1 at exactly one T2
Rule 3: It is obligatory that the participant 2 verb3 exactly one event 2 at exactly one T1
Rule 4: It is obligatory that the participant 3 verb4 exactly one event 2 at exactly one T2
Rule 5: It is obligatory that exactly one event 1 immediately precedes exactly one event 2
Rule 6: It is obligatory that exactly one T1 of event 1 immediately precedes exactly one T2 of event 1
Rule 7: It is obligatory that the T1 of event 2 immediately precedes exactly one T2 of event 2

The declarations of time as depicted in Rule 6 and Rule 7 are a solution to indicate and to inform which interaction is performed initially. For instance, Rule 6 relates with Rule 1 emphasising the participant 1 initiates the interaction by sending the event 1 which is followed by participant 2 who will be receiving the event 1 immediate after (the interrelated between Rule 2 and Rule 7).

The following figure illustrates the possible visual representation from the above specification of SBVR model.

$p_1 \rightarrow p_2 : e_1$ and $p_2 \rightarrow p_3 : e_2$ in Figure 3 illustrates the specification of SBVR model for Rule 1-2 and Rule 3-4, respectively. The down arrow in between those interactions showing the sequential reflects the specification of Rule 5.

Pomset of choreography [36] is an injection of g-choreographies to capture the causal dependencies of the services interactions in choreographies. It illustrates the transition of one interaction - by sending and receiving of the message, to another interaction - by sending and receiving of the other message. In pomset, semantic is labelled by actions: ! represents sending, i.e. $p1p2!e1$ specifies the sending of message $e1$ from $p1$ to $p2$; ? represents receiving, i.e. $p1p2?e1$ describes the receiving of message $e1$ by $p2$.

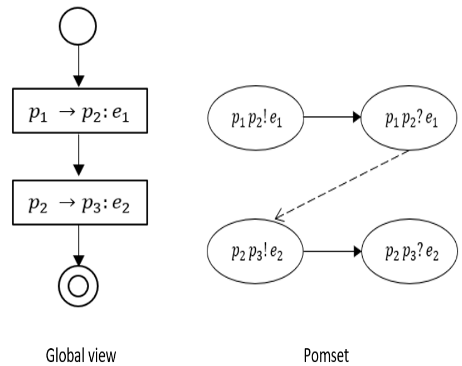

Fig. 3: Visual representation of global view and pomset for SBVR model (Rule 1 - Rule 5)

The use of pomset enables to visualise the notion of time in SBVR model to specify the ordering of sending (receiving) the same event as declared in Rule 6-7 (see Figure 3). Simple arrows in Figure 3 illustrates the aforementioned ordering, on the other hand the dotted arrow shows the dependency between those two interactions capturing the sequential composition.

The following rules are the specification for illustrating the complex interactions in SBVR model : the alternative interaction by defining OR over the event terms. This means, by referring to Rule 8, the participant 1 has the possibilities to select at least one of the events (OR) to perform the interaction. The receiver, participant 2 will perform the correspond events as sent by the sender (Rule 9). Rule 8-9 and Rule 10-11 describe two interactions that must be happened in order as defined in Rule 12.

Rule 8: It is obligatory that the participant 1 verb1 exactly one event 1 or exactly one event 2, at exactly one T1
Rule 9: It is obligatory that the participant 2 verb2 exactly one event 1 or exactly one event 2, at exactly one T2
Rule 10: It is obligatory that the participant 2 verb3 exactly one event 3 at exactly one T1
Rule 11: It is obligatory that the participant 3 verb4 exactly one event 3 at exactly one T2
Rule 12: It is obligatory that exactly one event 1 or exactly one event 2 immediately precedes exactly one event 3

Figure 4 describes the specified SBVR rules (Rule 8 - 12) applying the visual representation of global view. Rule 8 and Rule 9 has depicted with the fork (as branches). The first fork shows only the event 1 is chosen, the second fork represents only the event 2 is sent and is received by the participant 1 and participant 2, respectively, the last fork illustrates whenever both of the events are selected to be executed by the participants concurrently. Here, the parallel

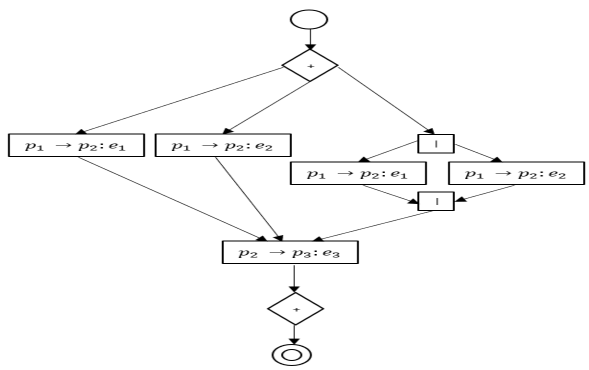

Fig. 4: Visual representation of global view for SBVR model (Rule 8 - Rule 12)

graph is applied. Rule 10 - 11 are specified as a single interaction, $p_2 \rightarrow p_3 : e_3$ occurs immediately after the previous interaction. This shows the sequential as declared in Rule 12.

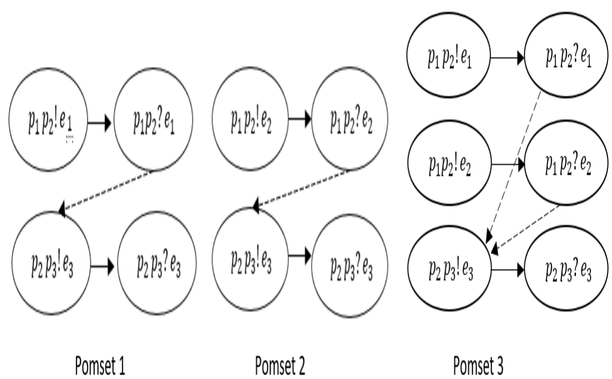

Fig. 5: Pomsets showing Rule 8 - 12

Figure 5 contains three pomsets defines three choices of interactions showing causal dependencies. Pomset 3 describes the occurrence of the event 1 and the event 2 at the same time which are sent by the participant 1 and received by the participant 2.

3.2 Correctness of mapping

The visual representation as well as pomset enlighten the interactions among the autonomous participants and the sequential composition which corresponds to the Alloy Model generated from the SBVR model of the choreography.

Correctness of the mapping concerns the correctness of the model transformation between the generated instance (choreography) in Alloy and the global view obtained as the visual representation, from the SBVR model specification.

The transformation here follows what was described in Section 2.3. Figure 6 represents the global behaviour of the choreography by the aforementioned specifications (in the previous section) for Rule 1 till Rule 7. The visualisation in Alloy making them easier to understand translating directly and explicitly from the specified SBVR rules. As shown in figure, the yellow box stated participant1 is pointed (arrow: verb1) to the event1 which is mapped to T1_E1 with the arrow stated : at. This reflected the specified Rule 1. A similar mechanism is used to specify Rule 2-4. The ordering of the interactions between the message exchange of event 1 by participant 1 and participant 2, and the message exchange of the event 2 by the participant 2 and the participant 3, is depicted using a simple arrow states immediately precedes. It is pointed from the event1 to the event2. This described the specified Rule 5.

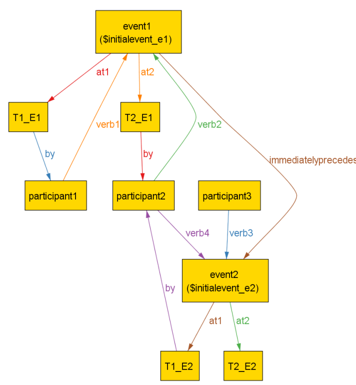

Fig. 6: The generated Alloy model for choreography from SBVR model (Rule 1 - Rule 7)

Rule 6 and Rule 7 are depicted in Alloy as in Figure 7. From the visualisation, it can be seen who takes the action initially and perform the next action in each interaction afterwards.

The following figure illustrates the generated choreography in Alloy model via transforming from the specification of SBVR model (Rule 8-12). Alloy does generate all possible executions it does not output them all in one graph, instead it includes a "Next" feature on its interface that allows the user to go through the possible executions one at a time. Therefore, it is not possible to show them all in one figure. Hence, there are three possibilities to present the alternative interaction encapsulates OR over two events, event 1 and event 2. The first graph indicates the participant 1 and the participant 2 execute the interaction by choosing the event 1 only, the second graph shows only the event 2 is se-

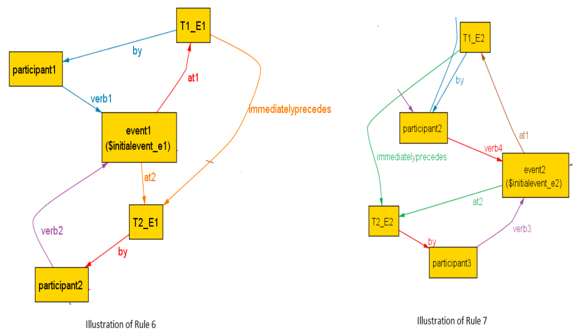

Fig. 7: The illustration of Alloy for Rule 6-7

lected, while the last graph represents both events are chosen concurrently. The similar illustration has been visualised by using the global view as depicted in Figure 4. Even both approaches has been specified with different semantics, the output represents the correctness of characterising the global constraints from the specification.

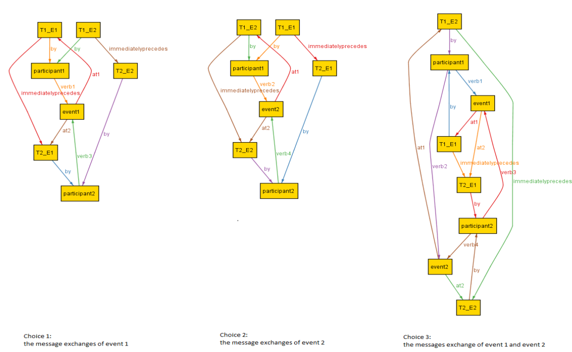

Fig. 8: The illustration of Alloy for the complex interaction OR over the event terms

Figure 8 also illustrates the visualisation of pomset in Figure 5. Both present the ordering of the message exchange of the same event by different participants.

All the visualisation of instance of Alloy model and the visualisation of global view including pomset, which both are mapped from the specified SBVR model, checking the correctness of both model transformation. Both approaches describe global behaviours capturing the key aspect in choreography: complex interaction and sequential.

4 Related work

The coordination of distributed service interactions is the primary concern of service choreography [26,2,6,4]. The majority of service interaction approaches have been provided for graphically defining service choreographies. Business Process Model and Notation (BPMN) [28,26,8] is user friendly choreographic models, represented graphically using notation but combine different semantics. The characteristics of BPMN is similar to Unified Modeling Language (UML). UML is a widely-known standard specification language for constructing service interactions [31]. Another language for choreography specification is Web Services Choreography Description Language (WS-CDL) [18]. WS-CDL proposes a metamodel-driven transformation technique consisting of a collection of Atlas Transformation Language (ATL) rules which refines WS-CDL choreographies towards executable Business Process Execution Language for Web Services (WS-BPEL) orchestrations. However, WS-CDL is unable to acknowledge and establish a way for verifying conformance to choreography specifications. [21].

Moreover, the work on a declarative approach to service interaction coordination is sparse. e.g., [3,12,22]. The focus seems to be more on reasoning about the consistency of the rule set, which of course is an important aspect of verification, and less on explicitly capturing the orderings in terms of observable message exchanges. The work on DecSerFlow [8] includes a graphical interface for user interaction but this is proprietary notation. In contrast, our approach uses SBVR for this purpose, which was developed with the business user in mind and is a standard maintained by OMG.

The OMG defined Decision Model and Notation (DMN) [29] is a design language and basic notation for describing decision rules. It is another well-known standard specification language for modelling service interactions and providing graphical notations that are easy to understand [7,10]. In the same way that BPMN does for business processes, it provides an integrated notation for decision management. However, for each intermediate step, DMN proposes a long technical noun phrase, whereas SBVR stays much closer to what business people actually say. It can be argued that when compared to DMN, SBVR uses more natural business language.

Global graph represents as the global view of the choreography where multiple participants interact with each other [11]. Examples of similar approaches that applied global graph as the global view can be found in [9]. The counterexamples were visualised by global graph and identifies the possible misbehaviours from the message-passing systems. Moreover, [20] formalise the global view of the choreography for reversible computations approach. Additional work by [27] deals with synthesising the global graph which illustrates the universal structure of communications from CFSM. Although our approach are similar, our main concern of applying global graph are different as we applied visual representation as the global graph to perform the conformance mapping correctness of SBVR model into Alloy model.

5 Conclusion and Future work

SBVR and Date-Time Vocabulary is used to specify business models in a declarative manner. Alloy Analyzer, a SAT constraint solver, provides an automated means to generate and verify the realisability of the choreography generated from the SBVR model. Hence, a transformation from the SBVR model to the Alloy model has been developed.

The correctness of the conformance mapping has been described in this paper. The correctness is conformed between the generated choreography in Alloy model transforming from the specification of SBVR model and the visual representation of the global view translating from the corresponding SBVR model. The correctness is concerned when the generated choreography models capture all global behaviours particularly in terms of the global ordering constraints and the complex interactions describing alternative (choice) and parallel (concurrent) interactions.

In order to enable end-users to participate in the development of the SBVR model on their own and then transform the SBVR model into the Alloy model automatically, the $\widehat{\text{S}}$BVR2Alloy tool [16] has been developed. It can be used to express complex rules, with a focus on capturing constraints on the orderings of service interactions, including concurrent interactions [23]. The tool can be extended to include less common features of SBVR and indeed this is part of the future work planned. It could be used to impress the distinction between *obligation* and *prohibition* on a message being received. This also brings in faulty channels or erroneous communication which in turn points to the need for transactional guarantees [34,24] in choreographies of ecosystem composed services [35,25]. The ultimate goal is an automated tool for modelling business rules but also executing the corresponding SBVR model and offering a preview of all possible executions to both modellers and end-users so that the business model can be adapted or extended to better match the business need.

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