SERVICE INTERACTIONS COORDINATION (CHOREOGRAPHY MODEL) USING A DECLARATIVE APPROACH FROM SEMANTICS OF BUSINESS VOCABULARY AND RULES (SBVR) MODELS

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MASTER OF SCIENCE (MATHEMATICS)

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ABSTRACT

Coordinating the interactions between autonomous participant services from different providers is a complex challenge when developing distributed applications. This research aims to develop an improved technique for modelling, generating, and verifying services interaction applying choreography approach which emphasises on a declarative approach based on the Object Management Group (OMG) standard, that is Semantics of Business Vocabulary and Rules (SBVR). An enhanced choreography model, called an SBVR model, can develop the choreography model by employing deontic rules, including both obligation and prohibition rules. The generated SBVR model is then transformed into an Alloy model using the Alloy Analyzer constraint solver, enabling automatic generation and verification (conformance and realisability) of the choreography model. This study also applies a global graph for proving the correctness of transformation SBVR model into Alloy model. In conclusion, this research has strived to add new knowledge to the current research by improvising the technique for modelling and generating the choreography model, allowing the conformance and realisability verification, through an SBVR-based choreography approach. The injection of prohibition rules into the model enables the choreography specification to capture not only what needs to be obligated but also what needs to be prohibited. The contributions of this research are significant in enabling non-expert users to effectively coordinate services and validate choreography models. This is achieved through the direct reading of the SBVR model, expressed in natural language, thereby enhancing comprehension for users without specialised expertise. The

developed SBVR model, represented in formal logic, is also suitable for parsing and verification purposes.

ABSTRAK

Bagi merangka interaksi yang melibatkan pelbagai perkhidmatan iaitu peserta autonomi (yang tidak bersandar antara satu dengan yang lain), seperti komponen perisian, perkhidmatan web, dan sumber dalam talian, merupakan cabaran yang kompleks apabila membangunkan aplikasi teragih. Penyelidikan ini bertujuan untuk membangunkan teknik yang lebih baik untuk memodelkan, menjana dan mengesahkan interaksi yang belaku dengan menggunakan pendekatan koreografi serta memberi penekanan pada pendekatan deklaratif berdasarkan piawaian Object Management Group (OMG), iaitu Semantics of Business Vocabulary and Rules (SBVR). Model koreografi yang ditambahbaik, yang dipanggil model SBVR, boleh menghasilkan model koreografi dengan menggunakan peraturan deontik, termasuk peraturan modaliti "obligatory" dan "prohibition". Model SBVR yang dihasilkan kemudiannya ditransformasi menjadi model Alloy menggunakan penyelesai kekangan Alloy Analyzer, membolehkan penjanaan dan pengesahan automatik (conformance dan realisability) model koreografi. Kajian ini juga menerapkan graf global untuk membuktikan ketepatan transformasi model SBVR ke model Alloy. Kesimpulannya, penyelidikan ini telah berusaha untuk menambah pengetahuan baru kepada penyelidikan semasa dengan memperbaiki teknik untuk memodelkan dan menjana model koreografi, membolehkan pengesahan conformance dan realisability, melalui pendekatan koreografi berasaskan SBVR. Suntikan modaliti "prohibition" ke dalam model, membolehkan spesifikasi koreografi bukan sahaja fokus pada apa yang perlu diwajibkan tetapi juga apa yang perlu dilarang. Sumbangan penyelidikan ini adalah signifikan dalam membolehkan pengguna bukan pakar untuk menyelaraskan

koordinasi interaksi dengan berkesan dan mengesahkan model koreografi. Ini dicapai melalui pembacaan langsung model SBVR, yang dinyatakan dalam bahasa semula jadi, sekali gus meningkatkan pemahaman bagi pengguna tanpa kepakaran khusus. Model SBVR yang dibangunkan, yang diwakili dalam logik formal, juga sesuai untuk tujuan penguraian dan pengesahan.

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APPROVAL

The Examination Committee has met on **5 August 2024** to conduct the final examination of **Nor Najihah Binti Zainal Abidin** on his degree thesis entitled **Service Interactions Coordination (Choreography Model) Using A Declarative Approach From Semantics of Business Vocabulary and Rules (SBVR) Models.**

The committee recommends that the student be awarded the of Master of Science (Mathematics).

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Academic session : 2024/2025

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LIST OF ABBREVIATIONS

B2B	-	Business-to-Business
BPNM	-	Business Process Model and Notation
CFSM	-	Communicating Finite State Machine
DMN	-	Decision Model and Notation
DL	-	Description Logic
DTV	-	Date-Time Vocabulary
ID2SBVR	-	Informal Documents to SBVR
LSC	-	Live Sequence Charts
LTs	-	Labelled Transition Systems
OCL	-	Object Constraint Language
OMG	-	Object Management Group
PAT	-	Process Analysis Toolkit
SBVR	-	Semantics of Business Vocabulary and Rules
SOA	-	Service Oriented Architecture
SOC	-	Service Oriented Computing
SQL	-	Structured Query Language
UML	-	Unified Modeling Language
uMSDs	-	Universal Modal Sequence Diagrams
W3C	-	World Wide Web Consortium
WS-BPEL	-	Business Process Execution Language for Web Services
WS-CDL	-	Web Service Choreography Description Language

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CHAPTER 1

INTRODUCTION

1.1 Background

The development of distributed applications depends heavily on the coordination of service interactions. (Steinau et al., 2021). Distributed applications involve an interaction of various autonomous participants, such as internet resources, web-based services, and software elements across different providers (Viroli et al., 2019). The interactions occur by exchanging messages through the participants' interface invocations. Participants in choreography are independent individuals that engage with one another by exchanging messages. The coordination of services interaction is very complicated. It is more obvious when the interactions are decentralised coordination, loosely coupled services, involving autonomous participants and the ordering of service interactions. Thus, the complexity of coordinating service interactions highlights the significance of the procedures and methods (techniques) needed to design and coordinate the interaction between participants, for ensuring the successful achievement of the overall goal of coordinating service interactions.

Service Oriented Computing (SOC) is a paradigm that focuses on the development and coordination of distributed applications over networks (Bhagya et al., 2019; Papazoglou, 2003). Service interactions are coordinated using either two primary approaches: service orchestration or service choreography.

Figure 1.1 illustrates a service orchestration that is a centralised approach in which a central service (orchestrator) is responsible for coordinating the execution of a composite service by orchestrating the interactions among other services (Arellanes & Lau, 2020). Service orchestration is well-suited for static environments, but it falls short of capturing the dynamic interaction that can occur between various services (El-Kassabi et al., 2023). Dynamic interaction encompasses the real-time changes or exchanges that can emerge among various autonomous participants during their execution (Zeng et al., 2022).

On the other hand, **Figure 1.2** illustrates service choreography emphasises global interactions and offers a more flexible approach to coordinating service interactions (Tveretina et al., 2020). In addition, service choreography involves the interaction of participant services in a decentralised and loosely coupled network (Tveretina et al., 2020). In this approach, each service communicates with other services in a peer-to-peer manner, without the need for a central coordinator. Service choreography enables services to autonomously communicate with each other, leading to a more flexible system. It is essential in service choreography to manage and coordinate the ordering of service interactions that comply with an agreed contract as prescribed in a set of global constraints, in a decentralised manner (Arellanes et al.,

2023) service interactions that comply with an agreed contract as prescribed in a set of global constraints, in a decentralised manner (Arellanes et al., 2023).

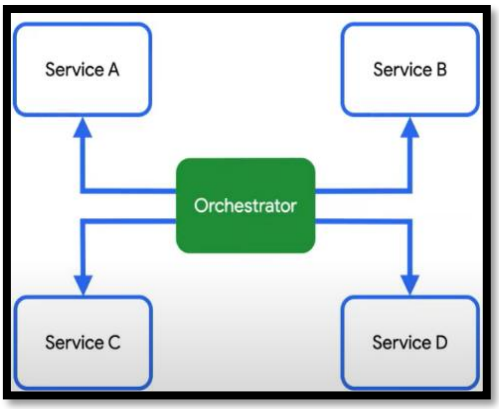

Figure 1.1 Illustration of service orchestration

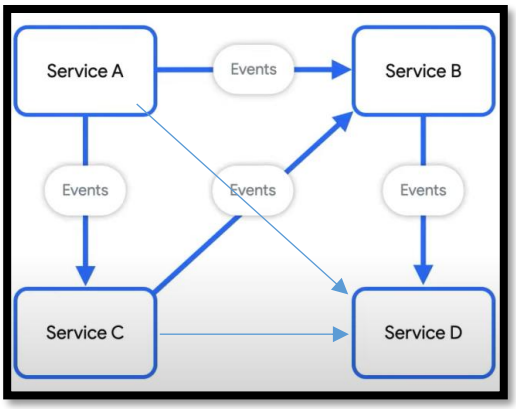

Figure 1.2 Illustration of service choreography

Service choreography is chosen for coordinating service interactions in distributed applications due to its inherent advantages. Its flexibility and decentralised nature enable services to communicate in a peer-to-peer way, promoting autonomy and adaptability. The loosely coupled network in choreography reduces dependencies between services, enhancing system resilience to changes and facilitating easier maintenance. This approach allows for global perspectives in managing interactions, emphasising overall behaviour rather than central orchestration. Additionally, service choreography's decentralised control facilitates the management of operation sequences, making it particularly suitable for scenarios where dynamic changes in interactions occur. Overall, its adaptability and capability to manage dynamic interactions make service choreography a preferred choice for coordinating service interactions in distributed applications.

One of the challenges faced in coordinating choreography is verifying the conformance and realisability of choreographies. Verification of conformance and realisability based on service choreography refers to the process of validating whether the service interactions can accurately and effectively follow the global behaviour of the predefined choreography (Schewe et al., 2020). Conformance verification focuses on validating whether the actual behaviour of the involved participants precisely matches the predefined choreography specifications (Prybila et al., 2020). This process entails confirming that the observable behaviour of the services aligns with the interactions and message sequence as defined by the choreography (Dai et al., 2020). Realisability, in the context of service choreography, refers to the feasibility of implementing a choreography with the participants' services that can interact according to the choreography's specifications (Schewe et al., 2020). It is concerned with the question of whether there exist service interaction implementations that can engage in the prescribed interactions without any deadlocks, mismatches, or other issues that would prevent the choreography from being executed as intended (Schewe et al., 2020).

Upon specifying service choreography, two main approaches are commonly used: the declarative approach and the imperative approach. The declarative approach aims at the desired outcome (“what”) rather than the step-by-step (“how”) procedures to achieve it. This approach is beneficial because it allows for flexibility in how the outcome is achieved, which can lead to more efficient solutions (Autili et al., 2020). The imperative approach, on the other hand, specifies the sequence of steps on how to achieve the desired outcome (Autili et al., 2020).

Examples of declarative models include DecSerFlow, Decision Model and Notation (DMN), Structured Query Language (SQL), and Unified Modeling Language (UML). DecSerFlow is a declarative language that can be used to specify and verify service choreographies(Van Der Aalst & Pesic, 2006). Conversely, DMN is a modeling language and notation used to precisely specify business rules and business decisions. (Hasić & Vanthienen, 2019). Furthermore, SQL is used for managing and querying relational databases. “SELECT” queries in SQL are declarative because they specify what data to retrieve without detailing how to perform the retrieval (Dev, 2022). Moreover, UML provides a set of visual tools and constructs for representing the structure and behaviour of systems, making it a declarative modelling language rather than an imperative one (Abdulmonim et al., 2019). These languages of specifications emphasise the portrayal of interactions, roles, and behaviours among participants without delving into the step-by-step actions on how they perform. In the declarative approach, business rules can be defined in natural language for the business process, making it intuitive and easy to comprehend.

On the other hand, an example of an imperative model is the Web Service Choreography Description Language (WS-CDL), Business Process Model and Notation (BPMN), Mealy Services and Vector Language. The WS-CDL (WS-CDL 1.0, 2005), was introduced by the World Wide Web Consortium (W3C) in 2005. This language makes it possible to describe web service interactions from a global viewpoint, providing a standardised way of coordinating these services (Yeung, 2007). It uses an XML-based language to specify how participants in the web services can interact to achieve a common goal, and it allows for the dynamic interaction of business processes (Barati, 2020). BPMN's choreography diagrams can express the

sequence of interactions among multiple participants or services using a more imperative visual notation. It outlines the flow of messages and events between services, detailing the sequence and conditions of message exchanges (Butleris et al., 2017; Corradini et al., 2020). Mealy services, derived from automata theory, embody an imperative methodology focusing on meticulous step-by-step instructions and formal specifications to ensure system correctness and reliability (McMillan & Zuck, 2019; Singh et al., 2019). Concurrently, vector languages, known for their proficiency in handling arrays and enabling parallel computations, offer efficiency in data processing and manipulation(Yodaiken, 2022).

In summary, the drawbacks of the imperative approach in choreography that the declarative approach could overcome encompass several key points. Imperative methods, such as those seen in BPMN choreography diagrams, tend to create complex, specific representations detailing sequences and conditional flows between services, leading to complexity and tight coupling with individual service implementations (Holzinger & Kommenda, 2020). This complexity poses challenges in understanding and modifying the choreography. Conversely, declarative approaches offer higher-level descriptions, abstracting away from detailed sequences, which reduces complexity and tight coupling, enhancing comprehensibility and flexibility (Steinau et al., 2021). Maintenance in imperative models often faces hurdles due to rigidly defined sequences, demanding substantial rework for modifications. Declarative approaches, focusing on "what" rather than "how," provide greater adaptability and ease of maintenance, allowing modifications without extensive rework. Moreover, the declarative approach's flexibility enables easier adaptation to dynamic changes in service interactions, making it more resilient and adaptable to evolving business

requirements (Kang et al., 2020). Furthermore, by using a declarative approach, the model can accurately represent the rules and constraints of service interactions, allowing for better validation (Agostinelli et al., 2021; Chun et al., 2019).

In this research, a declarative approach from the Object Management Group (OMG) standard, that is Semantics of Business Vocabulary and Business Rules (SBVR) is applied to developing a choreography model. A rule-based modeling technique is used in the proposed framework (model) for service choreography, known as an SBVR model. Natural language is used in the SBVR model to express the choreography specification, hence it is easy to comprehend, allowing the end-users (such as stakeholders and business analysts) to directly validate the specifications by reading the rules specifications. This has been highlighted and proposed by some researchers who suggest implementing a mechanism that allows end-users to participate in coordinating service interactions more easily. This approach emphasises the need to express business requirements declaratively using natural language sentences (E et al., 2019), thus would facilitate the implementation of choreography and allow end users to participate. The industry's reluctance to adopt existing choreography languages can be attributed to this lack of user involvement during specification (Dasari et al., 2020). Allowing end-user participation in specifying and coordinating service interactions paves the way for automated methods for analysing and verifying (realisability and conformance) the choreography (Autili et al., 2015).

Moreover, the SBVR standard (OMG, 2019) provides a backbone of formal logic, therefore the proposed SBVR model has the ability to represent and validate complex service interactions accurately (Azzini et al., 2021).

The specification of complex interactions, including alternative and concurrent interactions as well as the ordering of the services interactions, is captured by the proposed SBVR model. To specify the complex interactions and the ordering in which the service interactions occur in the SBVR model, the logical formulations of SBVR standards such as the logical operations, projections, and objectification, and the Date-Time Vocabulary (DTV) (OMG, 2017), are exploited.

The proposed SBVR model emphasises describing service interactions (service choreographies) using a deontic rule that expresses obligation and prohibition. The deontic rule defines business processes as mandatory guidance, which are regulated and enforced by an organisation, allowing for a more accurate representation of obligations and prohibitions within the coordination of service interactions (Sajjad et al., 2019). The deontic rule proves to be more valuable when working with coordinating service interactions, as it aligns with the global constraints of service choreographies (Abidin et al., 2021; Ivanovi et al., 2022.; Osman et al., 2006).

The complete choreography specification of the SBVR model is subsequently transformed into the Alloy model using Alloy Analyzer in order to validate the generated SBVR model. The Alloy Analyzer is an effective verification tool with several benefits. It provides automated verification, allowing developers to check their specifications against various scenarios, thereby reducing troubleshooting time and enhancing productivity (*The Benefits of Automated Step-up Verifications | Alloy*, 2023). The generated SBVR model serves the purpose of visually representing the complex interactions and the sequence of interactions within the choreography. The Alloy Analyzer verifies conformance and realisability by translating specifications