Interactive Resolution and Prevention of Inconsistencies in Business Rule Management

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Abstract

To define allowed company behavior, regulations are often represented in the form of business rules. As rule modeling is an incremental and often collaborative process, there is a high risk for contradicting rules being modeled. To date, several approaches for the detection, measurement and automated resolution of such inconsistencies have been introduced. While these approaches are an important first step towards successful compliance management in companies, they are currently incapable of providing resolution strategies that are applicable in a real-life company scenario. This calls for novel resolution approaches with possibilities for human intervention. By providing human experts with inconsistency metrics and visualizations, we hope to improve the understanding of inconsistencies, which is a prerequisite for a successful human-in-the-loop integration. Additionally, we will identify sources of inconsistencies to develop a general framework for the prevention of inconsistencies already during modeling.

Keywords

Business Rules, Business Rule Management, Inconsistencies, Inconsistency Resolution, Inconsistency Prevention, Explainability, Human-in-the-loop

1. Introduction and Related Work

Company operations are limited by an increasing amount of internal and external regulations. Especially as violating such policies might come with major legal consequences, managing compliance is a current challenge for organizations [1]. In this context, regulations are often represented as behavioral business rules, which can be defined as conditions in the form of a declarative statement that define allowed behavior of company processes [2]. Business rules are expressions of the general form $a_1, \dots, a_n \rightarrow b$ with $a_1, \dots, a_n$ representing the condition and b representing the conclusion of a rule.

Business rules originate from different sources and can be modeled either manually or automatically. Manual authoring of business rules is often a collaborative and incremental process, which increases the likelihood of erroneous rules being modeled [3]. Furthermore, rule mining can be applied to automatically extract business rules from already existing sources such as event logs [4,5], process models [6,7] or natural language [8,9]. As current approaches only focus on the extraction of rules in general, without taking potential interrelations between rules into account, the resulting rule sets might contain contradicting statements, which are referred to as inconsistencies.

Generally, we distinguish between different types of inconsistencies. In addition to inconsistencies in the classic-logical sense, which can be assessed already at design-time, recent works [10,11] have introduced so-called potential inconsistencies that comprise both *actual issues* and *potential issues* and can only be assessed at run-time. Actual issues describe rules that lead to contradictory conclusions as soon as their shared condition is met (e.g., $\{a \rightarrow b, a \rightarrow \neg b\}$). While there already exist means to assess the inconsistency types mentioned above, little research has been directed towards potential issues. In contrast to actual issues, potential issues do not have a shared condition (e.g., $\{b \rightarrow d, c \rightarrow \neg d\}$). Thus,

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they only lead to contradictory conclusions if *multiple* conditions are met at the same time. As the individual rules might still make sense on their own, potential issues are particularly hard to assess and resolve. Lastly, hidden dependencies [12] between rules might also lead to problems. For simplicity, we will use the term *inconsistencies* for all types mentioned above in the remainder of the paper.

Currently, inconsistency handling is mainly located after the authoring phase of the business rules management (BRM) lifecycle (see Figure 1) [13], i.e., inconsistencies are usually identified, measured, and resolved *after* business rules have been modeled. Recent works include the measurement of both classic inconsistencies [14,15] and actual issues [10,11] in general, implementations of inconsistency measurement in DMN decision tables [16] as well as first inconsistency resolution approaches [17,18].

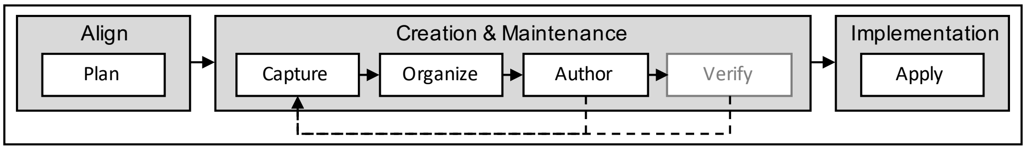

Figure 1: Business Rules Management Lifecyle (adapted from [13])

Regarding the latter, there currently only exist automated approaches that delete elements from a rule base to achieve consistency. While this is an important first step, it might not always be plausible or applicable in a real-world scenario, as this might lead to erroneous rules being kept, while potentially business critical rules are deleted instead. To solve this problem, it is not only important to include human experts but also to consider additional change patterns [19] (e.g., editing existing rules or adding context to rules) in novel **inconsistency resolution approaches**. While the deletion of rules can only lower the overall inconsistency of a rule base, changing rules might result in the creation of additional inconsistencies, which must be prevented as part of a resolution strategy. In addition to resolving existing inconsistencies, it is also important to focus on the **prevention of inconsistencies** already during rule modeling, i.e., in the capture, organize or author phase of the BRM lifecycle (see Figure 1).

Thus, we will address these two research gaps by developing interactive inconsistency resolution and prevention strategies, as further described in the following section.

2. Research Aim and Methodology

The aim of this thesis is to provide a continuous and interactive management of inconsistencies in business rule bases across the entire BRM lifecycle. This not only includes interactive approaches for measuring, visualizing, and resolving already existing inconsistencies, but also preventing inconsistencies from being modeled in the first place. Here, the focus is on a strong human-in-the-loop integration, as this aspect is crucial for the applicability of the results in companies.

2.1. Research Objectives and Questions

This work consists of four main research objectives (RO) and their corresponding research questions (RQ), which are described in more detail below. All objectives are closely interrelated and build upon each other, which is visualized in Figure 2.

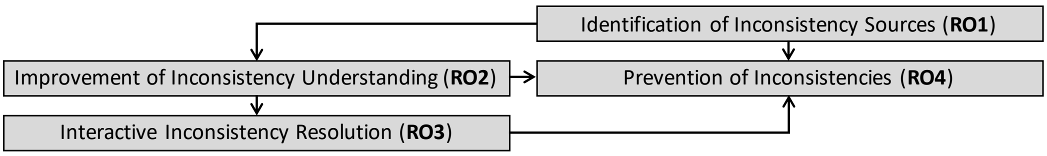

Figure 2: Research Objectives and their Interrelations

As a foundation for the prevention of inconsistencies (RO4), it is important to first identify their exact origin. Here we distinguish between two types of rule modeling, namely manual and automatic modeling. As manual modeling is often an incremental and collaborative process, our first goal is to better understand the manual modeling process and identify the causes for potentially inconsistent business rules. Additionally, inconsistent business rules can originate from rule mining, i.e., automatically extracting rules from event logs, process models, or natural language descriptions. Here, the aim is to understand which parts of these rule mining algorithms enable inconsistent business rules to be modeled as this is an important prerequisite for future resolution and prevention strategies. Thus, this objective leads to the first research question.

RQ1: *How do manual and automatic rule modeling approaches enable inconsistent business rules to be modeled?*

To develop interactive resolution and prevention approaches that involve human experts, it is important for humans to understand inconsistencies in business rules. Existing research on declarative process model understanding [12,20,21] has shown that especially combinations of constraints and hidden dependencies pose challenges to human modelers. This also leads to a lack of inconsistency understanding within such a model, which impairs their resolution and prevention. To solve this problem and to increase understandability of inconsistencies, we will make use of decision support technologies from the area of Business Intelligence (BI) [22,23]. The field of inconsistency measurement [14,24] already provides a number of quantitative measures for both entire rule bases and formulas within a rule base. In this work, we will focus on the explainability and extension of existing rule-based measures, as well as developing novel metrics, such as semantic and economic measures. In addition to providing the user with quantitative metrics, we will also develop and test novel inconsistency visualization techniques. Thus, the following research question will provide a strong foundation for the interactive resolution (RO3) and prevention (RO4) of inconsistencies.

RQ2: *How can quantitative metrics and visualization techniques improve the understanding of inconsistencies in business rules?*

The aim of the third objective (RO3) is to develop inconsistency resolution approaches with a strong human-in-the-loop integration. As current state-of-the-art approaches [17,18] solely apply (semi-)automated inconsistency resolution, we will first examine the applicability of these approaches to an interactive inconsistency resolution. Here, the focus will be on explainability, as the measures used in existing approaches mainly focus on guaranteeing minimal information loss as opposed to supporting humans in understanding inconsistencies and helping them to decide which rules are erroneous. The output of this objective will be an approach for a guided and stepwise inconsistency resolution, by integrating the inconsistency metrics and visualizations with the resolution approach itself. In this context, we will also investigate inconsistency resolution based on different change patterns [19], as changing a rule or adding context to rules might be more plausible in a real-life scenario compared to simply deleting rules from a rule base. Therefore, this objective leads to the third research question.

RQ3: *How can inconsistencies in business rules be successfully resolved in an interactive manner?*

To prevent inconsistencies already during rule authoring, we will integrate the results from RO1-RO3 and develop a general framework for inconsistency prevention, which is covered by the last research question (RQ4). Here, we also distinguish between manual and automatic rule modeling. To prevent inconsistencies during manual modeling, we will develop a procedure model containing best practices, based on the findings from RO1. Also, we will focus on the continuous support of consistent rule modeling by preventing inconsistencies *during* modeling, e.g., after only parts of the rule have been entered. To measure and visualize the impact of a current rule input, we will make use of the results from RO2, as an understanding of the current rule base and potentially arising inconsistencies is crucial for this step. In addition to identifying, measuring, and visualizing classic inconsistencies and actual issues directly, we will also develop means to predict and prioritize potential issues. Furthermore, we will develop approaches for consistent rule mining. Based on the findings from RO1, we will extend existing rule mining algorithms with novel parameters and develop entirely new approaches that take interrelations between rules into account to prevent the resulting rule base from being inconsistent.

RQ4: *How can inconsistencies already be prevented during rule modeling?*

2.2. Research Design

To develop and evaluate interactive inconsistency resolution and prevention approaches, we will apply a Design Science Research (DSR) methodology [25]. Table 1 provides an overview of the DSR phases, the respective RQs, and a description of each phase, including the applied research methods.

Table 1: DSR Phases and Research Methods

DSR Phase	RQs	Description
Awareness of Problem	-	To get an overview of the state of the art in the areas of BRM and especially inconsistency handling within business rule bases, an extensive literature review [26–28] has been conducted. The result of this phase is a research proposal containing the problem statement and identified research gaps that lead to the research objectives and questions guiding this work.
Suggestion	RQ1 RQ2	Immediately following the previous phase, the suggestion phase aims at developing a tentative design for the envisioned artifact. To this aim, we will not only conduct further literature reviews in the areas of manual and automatic rule modeling and process model understanding, but also apply qualitative research methods to better understand the manual modeling process and inconsistency understanding in general. This includes conducting interviews, case studies and eye-tracking experiments to gain both subjective and objective insights.
Development	RQ3 RQ4	Next, the tentative design is further developed and implemented. This includes the development of novel metrics and visualization techniques to improve inconsistency understanding, which then provide a strong foundation for the development of interactive inconsistency resolution and prevention approaches, which are the focus of this phase and this work in general.
Evaluation	RQ2 RQ3 RQ4	In this phase, the developed artifact will be iteratively evaluated and tested to analyze its behavior and identify required changes to the tentative design. At this stage, we will again focus on a close human-in-the-loop integration. To this aim, we will conduct experiments to evaluate the (cognitive) effects of the developed metrics and visualizations, as well as the entire resolution and prevention approaches.
Conclusion	RQ3 RQ4	This last phase will focus on the presentation and communication of results, as well as positioning them in terms of their contribution to knowledge.

3. Contribution, Current State and Outlook

The main contribution of this work is twofold. First, we will develop and evaluate explainable and interactive resolution approaches, which enables the applicability of inconsistency resolution directly in companies. Second, we will provide means for inconsistency prevention in the form of a general framework. Thus, this work will contribute to BRM by integrating inconsistency handling throughout the entire BRM lifecycle and preventing companies from having to detect, measure and resolve inconsistencies in the future. Additionally, the results of this work will contribute to research by identifying weaknesses of current state-of-the-art rule mining and modeling approaches and providing additional insights into process model understanding in general.

Regarding the current state of this work, the *Awareness of Problem* phase has been successfully completed and the focus is now on the *Suggestion* phase. In order to examine the potential of applying BI in the form of metrics and visualization techniques to improve inconsistency understanding, we have already conducted initial studies with human participants to not only test the effects of quantitative measures in general [29] but also the effects of visualization techniques on understanding inconsistencies in business rules [30,31]. Based on these results, we will now focus on further developing inconsistency metrics and visualizations that can serve as a basis for interactive resolution and prevention approaches. Furthermore, we have recently published a paper on an interactive and minimal repair of declarative process models [32] to show, how a human-in-the-loop integration could be combined with a semi-automated approach focusing on minimal information loss w.r.t. the number of deleted rules. As such a combination of automation and human-in-the-loop integration can provide many benefits, we will further extend this approach towards a stepwise and interactive inconsistency resolution as a next step.

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