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Identifying Ambiguity And Potential Violations In Standard Operating Procedures Using Natural Language Processing Tools

Karl Johnson[a], Caroline Morais[b], Edoardo Patelli[a]

[a]*University of Strathclyde, Glasgow, United Kingdom*
[b]*Agency for Petroleum, Natural Gas and Biofuels (ANP), Rio de Janeiro, Brazil*

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Standard Operating Procedures (SOPs) are vital in industrial environments, particularly in high-risk sectors like nuclear, oil & gas, and chemical processing. They dictate routine and emergency practices to ensure consistency, safety, and regulatory compliance (Home Office, 2007) (Serou et al., 2021) (Chervonenko, 2023). SOPs encompass purpose, terminology, roles, and step-by-step actions for managing daily tasks and critical incidents, thus forming the backbone of industrial safety management. Clear and precise SOPs are essential for consistent and correct procedure execution, reducing error risks and aiding effective training and communication within organizations. However, ambiguities in SOPs, often resulting from unclear language or lack of detail, can lead to inconsistencies, errors, and increased risk (Akyar, 2012). Such ambiguities can challenge even those deeply involved in their design and writing, as their familiarity might overlook practical operator perspectives (Manghani, 2011). Furthermore, intentional violations of SOPs, deliberate deviations from standard procedures, pose additional safety risks (Hudson et al., 1998). These violations are typically categorized into routine (habitual and often overlooked), situational (response to specific circumstances), and exceptional (rare, in extreme situations) types (Dougherty, 1995). Such violations, whether due to oversight or inadequate design, undermine the efficacy of SOPs and introduce significant operational risks.

To address these challenges, this work proposes the development of a tool that combines rule-based and machine learning approaches in Natural Language Processing (NLP). This tool aims to identify ambiguities in SOPs and flag steps prone to violations using historical data and ensuring they are not only comprehensive but also practical and adherent to safety protocols. This development represents a proactive approach to enhancing safety management and operational efficiency in high-risk industries.

SOPs, as well as texts in general, are inherently subject to various types of ambiguities, which present significant challenges in understanding. This work will focus on the following seven broad categories of ambiguities typically present in industry and procedure documentation (Ritcher and Koch, 2004); Lexical Ambiguity (multiple meanings of a single term), Syntactic Ambiguity (structure or grammar of sentences), Temporal Ambiguity (timing or sequence of actions), Quantity Ambiguity (quantity, amount and units), Conditional Ambiguity (triggering actions), Scope Ambiguity (scope or extent of a task), Abbreviation/Acronym Ambiguity (without proper definitions).

To identify such ambiguities within procedure guides a rule-based approach is suggested, this would involve the application of predefined and structured rules to analyze the text. These rules are crafted based on linguistic principles and patterns that are commonly known to lead to ambiguities. The rule-based approach is particularly advantageous due to its systematic nature, efficiency, clarity, adaptability, and ability to reduce subjectivity in analysis (Crowston et al., 2010). This method provides a robust algorithmic framework for the tool to identify ambiguities and potential areas of confusion in procedural texts. For example, regarding lexical ambiguity, the tool analyzes each step for any vocabulary that has multiple distinct meanings according to the chosen NLP

library. Any such steps are then highlighted/saved for further review. This process greatly aids in identifying potential ambiguities that may need addressing in procedural guides where clarity is crucial.

The International Oil and Gas Producers Association (IOGP) has compiled datasets on accidents and near-misses, providing valuable insights into violations and their impacts (IOGP, 2018). Using the violations present in the IOGP database, sections of other accident reports, that discuss or imply violations, were targeted and extracted based on specific keywords and phrases to build a comprehensive database of incidents involving violations. The source of these reports is the Multi-Attribute Technological Accidents Dataset (Moura et al., 2016), that represents a collection of over 200 accident reports from various industries analyzed using the Cognitive Reliability and Error Analysis Method framework (Hollnagel, 1998). This database is used to fine-tune a classification layer integrated with BERT (Bidirectional Encoder Representations from Transformers) a popular Large Language Model (LLM) (Devlin et al., 2018). This model has been selected for the tool's development based on its proven effectiveness when fine-tuned identify performance shaping factors in accident reports, and it's demonstrated capability to adapt to procedure guides without additional specialized training in such materials (Johnson et al., 2023). By training a model with data specifically related to violations, it is proposed that due to shared vocabulary and phrasing, the tool can identify procedural steps more likely to be vulnerable to potential violations. Highlighting such steps in the procedures will allow users to liaise with operators and identify the true operations and behaviors, that can then be reflected in the procedure steps, allowing for a more precise and beneficial task and safety analysis.

The ambiguity detection algorithm has demonstrated efficacy in extracting target sentences, informed by the application of the selected linguistic rules. This method has thus been effective in identifying ambiguous steps and instructions within SOPs. Further examination of the language and structural nuances of SOPs, leading to additional rules and refinement of the algorithms, is anticipated to enhance the precision of the ambiguity detection tool.

The violation detection tool underwent initial testing on incident and accident reports excluded from the training set, aiming to identify the occurrence of violations. The tool's strong performance, Precision of 84% and Recall of 76%, suggest that the tools violation prediction will transfer well to the intended application domain of SOPs, as was similarly demonstrated in (Johnson et al., 2023) where comparable performance scores were achieved. To further improve the tool's performance and to incorporate additional parameters, such as the type and severity of violations, it is necessary to continue the expansion of the database, as well as the training and testing of the model.

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