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# Quantum Natural Language Processing To Human Factor Identification In Accident Reports

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Quantum computing has garnered increasing attention in recent years due to its transformative potential to augment computational power (Stoos et al., 2023). This technology harnesses the quantum mechanics properties, such as superposition and entanglement to manipulate and represent data. Researchers have leveraged quantum hardware, and simulators, such as those released by IBM, to explore quantum applications across diverse domains, including, for example, chemistry (Bernal et al., 2022), and biomedicine (Cao et al., 2018). Despite the increasing use of quantum approaches in various fields, Quantum Natural Language Processing (QNLP) applications in Risk Analysis (RA) remain understudied, particularly in the aviation industry, where risk analysis is critical. Addressing this noticeable gap and building upon prior research initiated during the last ESREL conference (Macedo et al., 2023), our study endeavours to bridge the existing void. Specifically, this research involves a comparative analysis of various QNLP models to classify aviation accidents through binary classification, determining the presence or absence of human error as a causal factor. The proposed model streamlines the analysis for experts by automatically classifying accident narratives, allowing them to focus on critical aspects.

Our approach involves adopting Lambeq's pipeline (Kartsaklis et al., 2021) to convert sentences into quantum circuits. This facilitates the development of a QNLP model specifically tailored for determining the causal factors behind aviation accidents, with a focus on human error. This research not only contributes to the advancement of QNLP but also holds the potential to impact risk analysis practices within the aviation sector significantly. Recognizing the importance of automating the identification of accident causes, our model streamlines the analysis for experts by automatically classifying narratives. This efficiency allows experts to focus on critical aspects, bypassing the need to manually read through the entire accident narrative. The proposed model is applied to a comprehensive public database comprising accident investigation reports conducted by the National Transportation Safety Board (NTSB) from 1982 to 2022 (NTSB, 2022).

This database comprises over 20,000 documents organized into spreadsheets, offering detailed information on accidents, including occurrence dates, the number and severity of injuries, and distinctions between crew and passengers. Our primary emphasis, however, centres on the "accident description", a detailed narrative often containing crucial information about the accident's causes and consequences, and on the "accident cause description" providing, a shorter narrative of the accident's causes. Yet, this abbreviated description is neither consistently available nor standardized, posing challenges for experts seeking insights into common accident causes and proposing effective preventive measures. It is noteworthy that for our analysis, we randomly selected 200 narratives from this database and employed Summarization OpenAI to condense each narrative to 20 words due to the limitations of hardware and the number of qubits available. This summarization process allowed us to distil essential information from a substantial dataset, addressing constraints while retaining critical insights. Moreover, these reports were randomly separated into training and test data, more specifically 80% for training, in which 20% were separated for validation, and 20% for testing.

The first quantum model tested had the following configuration: TketModel as the Lambeq model, AerBackend as the backend that implements the necessary settings for the Lambeq model, SPSAOptimizer as the parameter optimizer, and Quantum Trainer as the "trainer". The Ansatz type "IQPAnsatz" was used for this stage. In all experiments, the proportion of datasets was the same and the number of epochs was set to 150. The second quantum model tested had the following configuration: Numpy Model as the Lambeq model, Quantum Trainer as the trainer, RotoSolveOptimizer as the optimizer, and StronglyEntangled as the Ansatz used in the parameterization stage. In this experiment, only 24 circuits were used for training and 25 epochs. Finally, we evaluated the performance of a hybrid model. To do this, the IQP-type Ansatz, Adam-type optimizer, and a custom Lambeq Model inheriting from the PennylaneModel class were used.

To compare the results obtained by the quantum models, we trained a classical model, using the same approach (i.e., based on string diagrams). The classical model achieved an accuracy of 73% and a total execution time of around 1 hour. The first quantum model showed an accuracy of 63%, taking over 8 hours to run. This also indicates regular performance and demonstrates that it is a very costly approach. The second quantum model optimized with the RotoSolveOptimizer proved to be highly costly, during the testing, the execution time already exceeded one hour. For this reason, training was carried out with a smaller number of training instances. With only 24 training instances and 25 epochs, this model took over 12 hours to train and had a test accuracy of 52.5%, presenting the worst balance between cost and performance.

The hybrid model achieved 80.48% accuracy in just over 1 hour of training, surpassing both purely quantum and classical models. It offers computational efficiency compared to purely quantum approaches due to the high cost of simulating quantum tasks on classical hardware (Sá et al., 2023). While the hybrid model shows promising results, challenges remain in developing reliable, scalable quantum computing systems. Furthermore, we compared the hybrid QNLP model with a traditional TF-IDF NLP model in a binary classification task. Despite quantum computing constraints, our study aimed to assess QNLP's efficacy against traditional NLP techniques. The traditional NLP model attained 93.125% accuracy, initially suggesting superior performance. However, qualitative analysis revealed its limitations in discerning nuanced semantic relationships, such as distinguishing between communication failure and pilot error. Conversely, the hybrid QNLP model demonstrated superior performance, showcasing its potential for enhanced accuracy in accident classification tasks.

It is essential to recognize that this field operates at the forefront of both knowledge and quantum hardware development. All analyses of purely quantum models in this study were conducted using simulation tools; thus, the anticipation is that, when implemented on quantum hardware, these models will not only operate at a faster pace but also deliver more accurate results. Additionally, QNLP offers unique benefits, including semantic extraction while preserving grammar, unlike classical NLP. Furthermore, QNLP shows promise by mitigating biases found in large language models through transfer learning. Quantum computing enables QNLP models with less data, enhancing control and transparency for more accountable outcomes. Moving forward, our research will focus on enhancing model robustness, validating performance against human expertise, and validating results on real quantum hardware to advance QNLP's application in risk analysis, thus enhancing safety measures.

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# Identification And Analysis Of Human And Organizational Factor Issues In Event Investigations: Key Findings From State Of Practice Survey

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In 2022, the NEA (Nuclear Energy Agency) Committee on Nuclear Safety Installations (NEA-CNSI), under the directive of the Working Group on Human and Organizational Factors (WGHOF), initiated the collaborative project, 'Good practices for investigators on identifying HOF (Human and Organizational Factor) issues from event analysis processes'. The project runs until 2025 and has as a main goal to compile a catalogue of practices useful for identifying HOF issues during the event investigation process. A first main activity in the project was to develop a detailed questionnaire to capture information about the practices used to identify and analyze HOFs in event investigation processes (Park and Solberg, 2023). The questionnaire was distributed electronically in December 2022. It contained questions about the practices related to forming the event investigation team, initial preparation, and plan of investigation, questions about the information to be gathered and the analysis methods and tools used, questions about the practices related to cause determination and root cause review, and questions about the practices related to event investigation report review and approval and dissemination of findings. These questions corresponded to 'Planning', 'Information gathering', 'Analysis', and 'Sharing and feedback' activities, respectively, which were identified as cornerstones of an event investigation process based on (Park and Solberg, 2023). It is noted that these cornerstones were originally suggested as major activities stated in IEEE Standard 1707-2015 (IEEE, 2015). Thirty-one responses were received from 11 NEA member countries, including Canada, Czech Republic, Finland, France, Hungary, Japan, Korea, Netherlands, Slovenia, Sweden, and Switzerland. Responses received represented practices used both in licensees ($n$ = 26) and by regulators ($n$ = 5). The findings from the survey will be published in a report summarizing the main results of the activities conducted in the collaborative project in 2022-2023 (Park and Solberg, 2024) Key findings extracted from this report are summarized below.

Key findings related to planning:

- Rules or a pre-defined catalog generally specify which kinds of events should be investigated. These include HOF or safety culture events.
- HOF specialists and senior managers are not always involved in the event investigation team when an event is suspected to be caused by or otherwise related to HOF issues. Furthermore, HOF-related training is not often required for event investigation team members who are not HOF specialists. These findings indicate that there is room for improvement based on current recommendations about the composition of the event investigation and their training (NEA, 2011).
- Most respondents did indicate that event investigation teams have the authority to conduct their work without interference, which is important when an event involves HOF issues (NEA, 2011).

Key findings related to information gathering and analysis:

- A broad range of information is gathered during an event investigation. Record review and interviews are generally used for this purpose. However, approximately half of the respondents indicated that guidelines and procedures are not in place to ensure the accuracy and ethical processing of information in line with industry standards (IEEE, 2015), indicating room for improvement.
- Information gathering was indicated to be most extensive in consideration of the present event. However, many respondents also reported collecting information about similar or analogous events, indicating that extent of condition is considered, as recommended by practice guidelines (IEEE, 2015). Around 40% of respondents indicated that information is also collected about previous success cases, i.e., where similar tasks were carried out successfully, where similar situations did not result in failure.
- Of the methods used to analyze events and extract HOF issues, HPES (Human Performance Enhancement System) or a variation of this method was most frequently identified as being used. The most frequently identified event analysis tools used were those comprised in the HPES method (e.g., barrier analysis, ECF charting, change analysis, task analysis). Methods such as MORT (Management Oversight and Risk Tree Analysis) and ASSET (Assessment of Safety Significant Event Team) were also indicated to be in use, but to a lesser extent. HPES is suited to analyze events that involve human factors, while MORT and ASSET were developed to analyze events with managerial and organizational issues. Thus, it is indicated that the event analysis methods most frequently used in practice are better oriented towards identifying human factors issues than organizational factor issues.
- Less than half of respondents indicated that there are guidelines to identify the tasks, actions, and decisions carried out by human operators that are important for explaining or understanding the progression of the event. Similarly, only half of the respondents representing licensees indicated that criteria were used for identifying human errors. (The availability of such criteria was higher among regulatory respondents.) Accordingly, findings indicate that there is room for improvement in establishing guidelines and criteria for identifying and analyzing human errors.
- Only about half of the respondents indicated that organizational or broader cultural aspects are considered as a factor contributing to human error, also indicating room for improvement.

Key findings related to sharing and feedback:

- About 60 percent of licensee respondents and 40 percent of regulatory respondents indicated having guidelines and processes in place to determine if an event investigation has been properly completed.
- Once complete, an event investigation report is often published. Respondents indicated that this most often only internally (within the organization where the event occurred). Distribution to reactor vendors and main suppliers occurs occasionally, but rarely to the public.

The findings from the questionnaire, summarized above, provide important insights about the event investigation practices currently used in NEA project member organizations. In 2024, a second main activity of the collaborative project, a comparison study, will be undertaken to help identify good practices from different possible approaches to investigating an event. The information derived from both activities will contribute to the main deliverable of the project, i.e., a catalogue of good practices that are useful for identifying HOF issues during the event investigation process, anticipated to be delivered in 2025.

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