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Application of machine learning to mapping primary causal factors in self reported safety narratives

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ABSTRACT

A new method for analysis of text-based reports in accident coding is suggested. This approach utilizes latent semantic analysis to infer higher-order structures between documents and provide an unbiased metric to the narrative analysis process. Results from this study on a small sample of aviation safety narratives demonstrates an unsupervised categorization accuracy of 44% for primary-cause within the existing taxonomy. If provided with a large sample set, the indication is that a significant increase in accuracy is possible along with the possibility of recoding between data sets. Demonstrated is the ability of LSA to capture contextual proximity of a narrative.

1. Introduction

Place yourself in the role of a safety manager, who is accountable for identifying and managing safety trends within your organization. A central element in assessing your organization's current safety climate and identifying safety trends involves making sense of voluntarily submitted safety reports. Several questions evolve for a safety manager attempting to make sense of a submitted report: "Is this incident of concern?" "Are other similar events happening within the organization?" "Does this report signify a trend?" "Is this an area of significant concern?" "What actions are appropriate to manage or mitigate this threat?" "What are the risks to the organization?" Central to answering these questions is the ability to efficiently identify reports of a similar nature within the organization and industry. Imagine having received the following narrative report.

> "After arrival at gate, the Flight Attendant disarmed door 2R and then proceeded to door 2L where he began opening the door without disarming it. Realizing his mistake, he attempted to disarm the door, but the gate agent outside the door began trying to open the door resisting the flight attendants attempt to close and disarm the door. The slide pack fell onto the cabin floor but did not inflate. Company personnel were summoned and took control of the situation. As Captain, I was still in the cockpit finishing the last of my cleanup procedures and was unaware of the events as no one notified me. I became aware of the situation only when going to the door 2L area where I became aware of what was going on." (ACN Report Number 839745, Primary Problem: Human Factors).

A safety professional, when confronted with a report narrative, engages in a process of sensemaking, parallel to that as described by Weick et al. (2005). Sensemaking ultimately answers the question of "what does an event mean?" (Weick et al., 2005, p. 410). Voluntary safety narrative reports play a role in the sense making process by providing a mechanism for collecting data that leads safety professionals to identify problem areas and discover meaningful trends. Coding taxonomies and text based searches provide safety managers with a tool for searching safety narrative databases for similar reports, useful in the sensemaking process. Machine learning techniques such as latent semantic analysis (LSA) provide an additional technique for safety managers engaged in sensemaking.

LSA aids the safety professional in understanding the meaning or significance of narrative reports, by relating them to other organizational events. This parallels the sensemaking steps of selection and retention described by Weick et al. (2005). LSA uses a different method from that provided by coding taxonomies to identify similar narrative reports. LSA has the potential to provide greater flexibility and to be more adaptive than traditional taxonomies. LSA matching provides an automated computer process for identifying similar report narratives that is less subject to

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human coding limitations and more efficient in terms of human effort.

To provide an illustration, consider the aforementioned voluntarily submitted report narrative. The LSA process allows the safety practitioner to generate a list of report narratives both within and external to their safety reporting system. In this case, the submitted report was compared using LSA with a sample database generated from the Aviation Safety Reporting System (ASRS). Using a predetermined threshold (cosine <0.50), 37 report narratives of a similar nature were identified. In contrast to a taxonomical search, which relies on a coding structure, these reports were heuristically generated strictly based on textual similarity. To illustrate a limitation of the ASRS taxonomy, these reports were coded by ASRS experts with a range of primary problems, including Aircraft (17), Human Factors (11), Ambiguous (8), and MEL (1). The narrative reports that follow indicate the closest narratives to our exemplar, as contained in our ASRS sample dataset, from the primary problem categories of Aircraft, Human Factors, and Ambiguous.

The nearest report coded with a primary problem of Ambiguous is as follows:

> Ready for pushback, Flight Attendant from door 2L came to cockpit to indicate that door 2L was not arming properly, that the wedge was not coming out. [I] went to door 2L to investigate. Looking at door, moved lever to disarm and looked again. Opened door handle and it was apparent that door was not disarmed, door with assist opened partially. Slide was attached at bottom and partly out of pack. I tried to close door but slide then deployed. No one was hurt; no one else was involved in manipulating the door. Maintenance was called and it was determined that the slide would be replaced and flight to operate with a delay. (ACN 1031966, LSA cosine 0.861).

The nearest report coded with a Primary Problem of Human Factors is as follows:

> I was the 'A' Flight Attendant and was feeling nauseous and dizzy during descent. When I reached down to disarm the L1 door I must have disengaged the girt bar and instead of attaching it above to disarm, I rearmed it. I attempted to open L1 door along with the Agent, when I realized the door was still armed. We closed and I disarmed the door, but the slide pack had dropped into a position that prevented us from opening the door. Maintenance had to be called to remove the slide pack. We deplaned. I believe that I am experiencing symptoms of a sinus infection. The dizzy, nauseous sensations I was having contributed to a potentially deadly mistake. Even though I cross checked myself, had the red flag up, and made my announcement I will always be conscious of how the door feels and aware of the dragging sound the slide makes when the door has not been disarmed and you attempt to open it. That final awareness saved me from one of my worst fears. (ACN 983720, LSA cosine 0.836).

The nearest report coded with a Primary Problem of Aircraft is as follows:

> This was a charter flight. The aircraft was parked in the north lot. Airstairs were brought to the aircraft door at 1L. It appeared the person trying to open the door was having difficulty opening the door. I cracked the door. He still appeared to be having difficulty, so I gave the door a push. The person on the other side was still having difficulty opening the door. I soon saw why. The side of the slide pan was caught on the side of the aircraft door. As the person on the outside continued to pull the door open the slide pan opened and the slide fell out, but did not deploy. A Mechanic arrived to detach the slide from the door. He said the door was armed. The arming mechanism was stuck between arm and disarm and we were unable to put it in either the arm or the disarm position. I told him that I disarmed the door. After I disarmed it, I made the all call to disarm cross check and stand by for all call…It is possible the next time a slide may in fact deploy. (ACN 969496, LSA cosine 0.832).

The similarity between the above reports should be self evident, despite differences in the primary problem coding. In each case, an inadvertent deployment of an exit slide was a possibility, as evidenced by the actual deployment in one case, and the reporter expressed concerns of a possible deployment in the other cases. In this case, use of the LSA process utilizing only the raw report narrative generated a list of 37 reports many of which are useful in the sense making process. These reports covered a range of primary problems and contributing factors. Of those reports, 16 reports dealt specifically with the improper arming or disarming of exit slides (including inadvertent deployments). 20 of the reports were related to improper door operation. The final report involved a damaged cockpit door.

In contrast, a similar search of the same database using multiple text strings was conducted. These search strings included "inadvertent slide deployment", "door AND disarm AND flight attendant", and "door slide OR exit slide OR inadvertent deployment OR improperly armed OR improperly disarmed". In total, the text based searches captured 11 of the LSA generated report narratives, of which seven related to inadvertent slide deployments. The LSA process generated 13 reports beyond that of our simplified text search. Anecdotally this indicates that the LSA process provides safety managers with an additional tool beyond coding taxonomies and text searches for identifying similar report narratives within large databases. The reliance of LSA on raw report narratives avoids the time and effort required to code incoming reports, overcomes the limitations of existing taxonomies, and provides additional flexibility in generating safety reports across databases.

1.1. Latent semantic analysis

The methodology of latent semantic analysis (LSA), developed by Deerwester et al. (1990), has seen many applications since original publication. The process has subsequently been applied to diverse fields of inquiry, from educational theory (Landauer and Dumais, 1997) to automated document classification (Liu et al., 2004; Landauer et al., 1998; Zukas and Price, 2003). Thus far, textual analysis techniques such as LSA have not been widely applied within the field of safety management, despite the abundance of narratives alongside other quantitative data. In aviation, accident analysis narratives are commonly used to manually discriminate factors developed through traditional statistical methods applied to quantitative data.

LSA is a mathematical technique for inferring relations between words within bodies of text. Without the assumptions of other language processing methods, LSA extracts the occurrence of words in a text body and creates a term frequency document matrix. A singular value decomposition (SVD) is applied to the resulting matrix. The central matrix from the SVD is then truncated by the substitution of the lowest values with zero. This truncated, or reduced space, form of the matrix then provides the inferred relationships between terms used in similar contexts. In this reduced space, term associations are made that are not present in any single body of text. Thus latent relationships are revealed by this method.

This application of LSA has been successfully used to match similar texts, answer multi-choice based subject tests, and predict subjective ratings of texts. Studies of document classification problems have indicated that accuracies up to 93% (Huang, 2003) are possible when LSA is combined with support vector machines