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MACHINE LEARNING APPLICATIONS FOR MONITORING CONSTRUCTION HEALTH AND SAFETY LEGISLATION AND COMPLIANCE

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The construction industry has, for many years, been subject to stringent health and safety legislation for the protection of workers and the public. To ensure compliance, firms must invest a great deal in resources. However, with different legislative requirements, deadlines, and fragmentation, it is easy to overlook something or implement wrong frameworks. This study aims to investigate the applications of unsupervised machine learning (ML) on monitoring health and safety legislation and compliance on construction sites. The paper provides a systematic and comprehensive review of literature from previous studies on ML applications in construction between the years 2005-2020. A literature search from online databases was conducted using keywords. A two-step literature filtration process was used to obtain relevant publications to meet the selection criteria. The findings of the study suggest that, as technology advances shaping the future of workplace safety, ML can be used to monitor compliance and set out recommendations for future standardizations in construction. Adopting ML in the can be used to process masses of information at better speeds and accuracy to make decisions and identify anomalies that would not have been identified by humans, improving compliance. This study presents the first attempt on the applications of ML for monitoring health and safety legislation and compliance on construction sites. Future research proposes to develop a tool for contractors to use to monitor compliance.

Keywords: Construction industry, Law, Artificial intelligence, Workers' well-being.

1 INTRODUCTION

The construction workers' health and safety are integral to any industry, and with stringent government legislation, employees are better protected by the law than ever before (Hazardex 2019). Nevertheless, workers are still exposed to hazards resulting in accidents in the workplace. Companies may well have far-reaching rules and regulations governing health and safety, but it can be difficult to engender full compliance (ibid). Regulatory requirements and regulatory complexity with which companies should comply are ever-increasing, and companies need to keep up with complex and ever-changing regulations (Giblin *et al.* 2005). The ever-increasing volume of legislation raises several opportunities for the confusion that often results in human error (Rottner 2019).

Traditionally, compliance has mainly relied on people and companies have had no choice but to employ more compliance staff in an effort to tackle the rising regulatory burden (Ershov 2018). Safety management systems on construction sites rely on subjective data analysis, expert

opinions, guidelines, and the perspectives of management (ibid). However, despite numerous efforts to improve health and safety on construction sites, traditional approaches have reached saturation and continue to fail, and innovations are required (Esmaeili and Hallowell 2012). Recently, technology is playing a greater role within the compliance and technological innovation can lift compliance burden (Bristow 2019). Past accident records can serve as the foundation for future accident prevention (Goh and Ubeynarayana 2017).

Companies and regulators are beginning to realize that emerging technologies such as machine learning (ML) and artificial intelligence (AI) could have a considerable impact on reducing the burden of institutions and compliance professionals as regulatory compliance grows more technology-driven every day (Ershov 2018). The applications of ML could be valuable in alleviating human error (Rottner 2019). AI and ML can identify blind spots and other errors that humans may overlook (ibid). Furthermore, using AI techniques such as machine learning, companies can automate data allowing companies to carry out processes with a higher degree of accuracy (ibid).

AI and ML have proven beneficial in studying accidents in the construction industry; however, little is understood on autonomous applications of ML in the field of construction health and safety. Human error is unavoidable; however, AI platforms such as machine learning never get tired and are more accurate at spotting issues, especially in industries such as construction where workers are exposed to hazards and simple mistakes can lead to serious consequences. This study aims to investigate the applications of unsupervised machine learning on monitoring health and safety legislation and compliance on construction sites.

2 METHODOLOGY

This study is an initial overview of the applications of machine learning on monitoring construction health and safety regulatory compliance in the construction industry. It is a literature review study, which forms part of ongoing empirical research. The study is based on machine learning research across all fields and its applicability in the construction industry. Relevant studies and research were primarily obtained from position papers, policy documents and scientific publications from online research databases such as Scopus and Web of Science. Database search was conducted using keywords such as Machine learning, Health and Safety, Artificial Intelligence, Legislation, and Compliance. The initial search revealed 649 documents across all subject areas as the word construction is a common term. The initial search was filtered to reveal only research from 2005 to 2020 with source titles: Automations in Construction, Advanced Engineering Informatics, and Artificial Intelligence and Law. Only seven papers were obtained. Articles reviewed were not sufficient to solely conduct literature findings and led to the adaptation of studies published in other fields such as the financial sector, which has advanced in the subject area. Publications cited in this study include publications from reputable scholarly journals, websites, and reports.

3 LITERATURE REVIEW

3.1 The Future of Compliance

Regulatory compliance has become increasingly challenging and attempts to engage IT solutions such as AI and ML are on the rise (Goltz and Mayo 2018). Advances in computer power, new algorithms, and big data have led to major breakthroughs in the development of AI systems such as machine learning (ML) (EC, 2018). To automate regulatory compliance in construction, there is a need to automate legislative requirements from different construction legislative documents and enable automated reasoning (Zhang and El-Gohary 2015). Currently, practical applications

of regulations rely on human interpretation followed by the deployment of a solution, with heavy penalties for noncompliance. The application of AI can help reduce the workload involved and improve accuracy (Bristow 2019).

3.2 What is Machine Learning?

Machine Learning is the ability of a machine or smart device to learn from data without being programmed (Joshi 2017). The main idea of ML is that a computer system autonomously improves its learning ability with time by working with larger reference data sets (Shahid and Woloszynski 2018). Machine learning systems include data mining, neural networks, and genetic algorithms (Kinston 2018). Machine learning is the main paradigm within Al and is concerned with learning from data (Goltz and Mayo 2018).

Machine learning is a useful prediction tool comprised of analytical tools classified as supervised and unsupervised learning tools (James *et al.* 2013). Supervised machine learning involves the creation of a statistical model that can predict an output based on one or more data inputs, while unsupervised learning comprises of a dataset that is analyzed by extracting features to show patterns or structures without any dependent variable in order to make estimates or predictions (James *et al.* 2013). The identification of patterns in a data sample enables powerful out-of-sample predictions (van Liebergen 2017).

One of the principal approaches of machine learning is deep learning, which is an approach based on both supervised and non-supervised learning methods (Najafabadi *et al.* 2015). Deep learning function mimics the workings of a human brain in processing and analyzing data (van Liebergen 2017). Deep learning to recognize all kinds of data, including low-quality data and unstructured data. These layers of landscapes are not designed by human engineers but are learned from the data using a general-purpose learning procedure (LeCun *et al.* 2015).

3.3 Opportunities

Machine learning is playing a vital role in regulatory compliance and its applications address common issues and systematic challenges encountered by compliance officers every day (Rottner 2019). While the potential benefits of machine learning are vast, their usefulness in compliance systems has revealed at least three distinct benefits for regulatory compliance officers, namely, decreasing false positives, lowering costs, and eliminating human error (ibid). Machine learning applications can assist compliance officers in managing workflow by autonomously classifying compliance-related tasks and notifying them about critical activities, updates, and events. Machine Learning algorithms learn from compliance officers' data; therefore, this enables machine learning to update compliance alert systems more accurately (Rottner 2019).

Machine learning promises to radically transform construction companies' ability to comply with relevant regulations by enabling construction companies to combine human experience with the unlimited ability of computer systems to consume large datasets and reduce the challenges of complexity (Shahid and Woloszynski 2018). Furthermore, the combination of robust, real-time monitoring, error recognition, and autonomous response mechanisms leverage machine learning to respond effectively to compliance issues in the digital time. Current applications of machine learning for regulatory compliance are already being utilized. For example, IBM's Watson Compare & Comply uses machine learning to identify, analyze, classify, and manage contracts, while at the same time detecting and managing risk (ibid).

3.4 ML in Construction Health and Safety Legislation

Construction companies are by law required to comply with a lot of health and safety regulations. The manual process of compliance checking is time-consuming, expensive, prone to error, and an array of regulatory bodies further make compliance seem like an unachievable task (Zhang and El-Gohary 2013). Alternatives such as automated compliance checking (ACC), as opposed to manual checking, are expected to effectively reduce the cost, errors, and time of compliance checking (Tan *et al.* 2010, Salama and El-Gohary 2013). The pace of regulatory developments, complexity, and interconnectivity of construction activities have increased beyond the ability of construction companies to efficiently manage compliance using unassisted human resources only (LR 2019). The need for legislative compliance is becoming more stringent (ibid).

Construction companies have a wide range of data sets that are rarely integrated, making it difficult to create one mineable source with permits to work, near-miss reports, job-hazard analyses, observations, audits, and inspection results (LR 2019). Furthermore, it is noted that the most useful information stays locked away in the free text description of the occurrence, where the clues lie, which could direct and help identify the root causes of accidents (ibid). Nonetheless, construction companies and compliance officers do not have enough time to examine the vast amount of data, whereas keeping track of all the changes (Lynch 2019). Machine learning applications may be used to scrutinize and interpret regulatory compliance documents (ibid).

3.5 Challenges

Since artificial intelligence systems such as machine learning rely heavily on learning the correct behaviors, it is important for these systems to learn from a good set of training data that yields the right outcomes (Shahid and Woloszynski 2018). Shahid and Woloszynsky further added that machine learning for compliance would have to take into consideration if certain data, subject to privacy protection, could be used to train the AI algorithms and also if the AI can use specific data to make compliance judgments. Like many previous technologies, it is plausible that despite the vast promise of machine learning in compliance, it might take some time for the technology to fully develop to a stage where it is generally adopted and widely successful. (ibid). Moreover, companies must be careful not to allow machine learning systems to develop biases, which could negatively affect decision making (Joshi 2017).

4 DISCUSSIONS AND RECOMMENDATIONS

Compliance with construction health and safety legislation is a must-do activity, not a nice-to-have. To be compliant, construction companies need to keep up with the ever-changing regulatory requirements to safeguard the health and safety of construction workers. However, it is challenging to remain compliant at a time when all activities are governed by their own set of legislative requirements. Whether attributed to poor due diligence, outdated technologies, or ineffective procedures as human error is inevitable. It is imperative for construction companies to adopt the benefits of artificial intelligence systems, such as machine learning, to ease the burden of regulatory compliance. By applying machine learning, both construction companies and regulatory bodies will focus on their roles as far as compliance with the regulations is concerned. Implementing technology is more about augmenting people. Machine learning can be used to boost efficiency and improve health and safety culture within construction firms and better protect workers by prompting workers with the right decisions, enabling health and safety managers to do their job more efficiently and with more accuracy.

Proper applications of machine learning for monitoring construction health and safety legislation and compliance could improve working conditions and, most importantly, lead to

better health and safety of the workers. One of the greatest components of ML is the ability to take unlimited information, learn from algorithms, and make autonomous decisions. It is recommended that construction companies implement ML applications to bank on as much data as possible to identify anomalies in legislative requirements and help improve construction health and safety. Although the construction industry is under-digitized, ML has the potential to drive growth and improve construction health and safety. Some construction companies are slowly realizing the benefits of ML, even though its applications, especially in construction health and safety are still limited. The implementation of ML in construction could significantly disrupt the way companies operate.

5 CONCLUSION

This study investigated the applications of unsupervised machine learning on monitoring health and safety legislation and compliance on construction sites. An extensive literature review was explored to identify machine learning applications for monitoring construction health and safety legislation and compliance. The findings of the study suggested that although the applications of ML have been applied to study accidents in the construction industry, there is still a lack of research in the field of construction health and safety. Most accidents are a result of human error and the applications of ML could alleviate the burden of compliance resulting from ever-increasing legislation. Notwithstanding the benefits of ML, there some concerns regarding training data sources as wrong information could result in biases, false positives, or wrong outcomes. Despite the current limitations, it is recommended that the augmentation of ML with safety personnel for monitoring construction health and safety legislation and compliance may result in full compliance and also track and monitor interactions of construction workers on construction sites in order to realize the full potential of workers.

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