Evaluating artificial intelligence tools for automated practice conformance checking

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Abstract –

Checking conformance of construction management practices to practice specifications is typically performed manually by experts in the Engineering and Construction (E&C) sector. Though conformance checking is known to increase performance of a project, this process takes considerable time as several professionals have to go through thousands of pages of documents, complex workflows, and personal interviews. This paper aims to evaluate AI tools including Text mining, process mining, and image data mining for their utility in assisting conformance checking in construction management. Automated conformance checking may not only reduce manual and repetitive work by experts but also reduce human errors. Examples are demonstrated for initial validation.

Keywords –

Conformance; Artificial Intelligence; Software Evaluation

1 Introduction

The Engineering and Construction (E&C) sector is slower to adopt new technologies than other industry sectors. Its conservative approach to new technology is partly due to its large scale which leads to greater risk and its complexity that involves many stakeholders. However, considering that a 1% rise in productivity could save $100B a year worldwide [1], the industry should move forward to exploit new technologies. Especially in the construction management field, the use of the state-of-the-art technology is promising.

Good construction management balances professional judgment with conformance to references such as best practices, policies, standards, and procedures. 'Conformance,' 'conformity,' and 'compliance' are used as synonyms. There has been intense debate on use of the words. ISO 9000:2000 suggested to use 'conformity' and drop both 'conformance' and 'compliance' for quality management system. The word 'conformance' seemed to have lost its status. However, according to ISO 9001:2015, 'conformance' is redefined as choosing to do something in a recognized way and 'compliance' is doing what one is told to do. Both words still exist and are widely used throughout the literature. While ISO still prefers to use the term 'conformity,' the term 'conformance' was selected for two reasons. First, 'conformance checking' is a term that already exists and is commonly used in the process mining field. This could maintain consistency and avoid confusion. 'Conformance' rather than 'compliance' was adopted because of the intention to define something less strict than abiding by the law or meeting regulations. Compliance fits better with laws or regulations, whereas conformance better suits with pursuing best practices, policies, standards and procedures.

'Checking,' 'measuring' and 'evaluating' imply different meanings, although commonality exists. Checking usually implies yes or no, true or false, or pass or fail. Measuring implies numeric results, and requires metrics, observations, and formulas to derive the values. Evaluating implies not only quantitative but qualitative assessments. This paper introduces tools that can 'check' conformance, and 'evaluate' commercial software. Thus, the objective of this paper is to evaluate how artificial intelligence (AI) technologies can be adopted to aid automated conformance checking in construction management.

In order to check conformance, relevant AI technologies were evaluated. AI is a generalized term for computers replicating human intelligence in learning, decision-making, vision, speech, etc. Text mining, process mining, and image data mining tools that have artificial intelligence background were investigated in this paper.

2 Literature Review

The concept of artificial intelligence (AI) existed since the 1950s, but the modern definition was built from research done in the 1970s. AI can be defined as a system that rationally thinks and acts like humans [2].

AI has been divided into parts, as the technology is still limited to integrate all capabilities in a single entity.

In E&C sector, AI has been constantly used to solve problems in structural engineering [3], transportation [4, 5, 6], and geotechnical engineering [7]. A conceptual model such as Industry Foundation Processes (IFP) for conformance checking has been developed [8] as well as Genetic Algorithms [9]. Though some researchers insist that much of them are often theoretical and are difficult to apply in the real world [10], the recent explosion of commercial applications of AI challenges that assessment.

For project management in E&C sector, AI was used to solve problems such as site-layout modeling [11] and generating construction project plans [12]. Levitt et al. [12] suggested that AI technology can provide ways to generate and update plans in actual project progress from stored knowledge. Tommelein et al. [11] enabled computers to mimic designer's layout and add flexibility and functionality to existing model.

Conformance checking and measurement has been investigated since early 1990s. Rajamani, and Rehof [13] developed a mathematical model for contract conformance. Abdul-Rahman [14] derived costs from non-conformance and suggested a quality cost matrix for construction projects. Yurchyshyna et al. [15] proposed an expressive model and a knowledge-based system for checking a construction project against technical norms by matching the project with the norms. Lipman et al. [16] reviewed and assessed conformance testing methods for product data models used in the construction industry. Nawari [17] optimized and simplified automated code and standard conformance checking by leveraging building information modeling. Zhang and El-Gohary [18] suggested Semantic Natural Language Processing (NLP) based information extraction for automated regulatory compliance checking.

3 Methodology

To measure conformance, four components were identified and they are illustrated in Figure 1. This paper covers documents and workflows components. However, people and actions are also included in these two components as people build and implement these components. For each component, what to check and how to check the conformance are also listed in Figure 1.

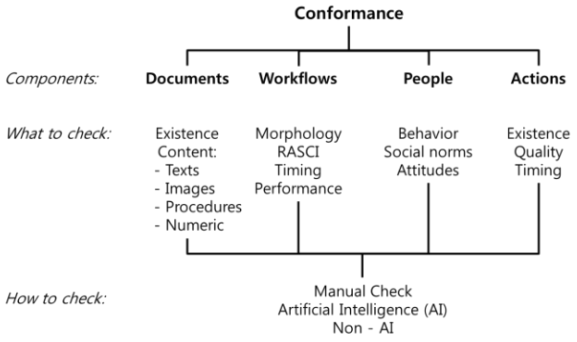

Figure 1. Conformance components

Despite the history of artificial intelligence (AI), application challenges remain in the E&C sector. The difficulty of identifying the appropriate tool to suit a new situation; the need for large amounts of input data for tools to be usable; the opaqueness of most tools; and the difficulty of realistically interpreting the solutions to highly tailored problems are some of the reasons behind [10]. On the other hand, this paper focuses on how to apply AI to improve conformance problems.

Throughout this paper, technologies that could be applied to check conformance are introduced and evaluated. Data mining is the computing process of extracting patterns in large data sets. Its goal is to transform the extracted information into an understandable structure for further use. Data mining is divided into three categories in this paper: text mining, process mining, and image data mining, and some AI tools are introduced (Figure 2).

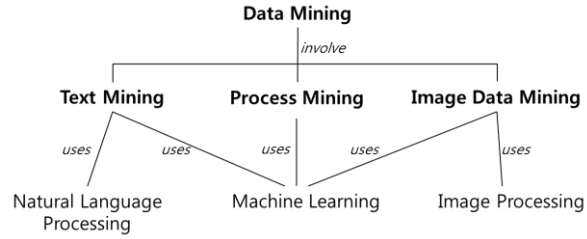

Figure 2. Tools for conformance checking

Text mining is the process of deriving high-quality information from text. Natural Language Processing (NLP) and machine learning algorithms can be used for text mining. NLP is an ability of computer software to understand human language such as speech and text. NLP is widely used to analyze large pools of legislation or documents. NLP can summarize blocks of text by extracting the central ideas and ignoring irrelevant information, automatically generate keyword tags and identify the sentiment of a text and reduce words to their roots using stemmer & lemmatization. Plagiarism detection tools, wordcloud generator tools and resume

screening tools utilize NLP technology in this paper.

Process mining is also part of data mining that requires specific data such as an event log (i.e. case ID's, activities, timestamps, etc.), and machine learning algorithms. With event logs, practical workflows can be derived (process discovery), and conformance to the driven workflow can be checked (conformance checking).

Image data mining is a technology that aims at finding useful information and knowledge from large scale image data. It enables computers to gain high understanding from digital images or videos. This technology is intended to convert an image into digital form to extract information.

Machine learning is the computer ability to learn without being explicitly programmed. Machine learning enables construction of algorithms that can learn from data and make predictions or decisions. Machine learning is used for all categories in data mining.

4 Case Studies

To facilitate understanding, some commercially available software for Natural Language Processing (NLP), process mining, and image processing are introduced. Explanation of the purpose of these software, and ways to adopt them from management perspective are presented.

4.1 Natural Language Processing (NLP)

Among all the Artificial Intelligence (AI) technologies, NLP plays a critical role, as documents are mostly in the form of text. NLP can be used for preprocessing such as detecting copy and paste with plagiarism detection tools, analyzing frequency of words with wordcloud generator tools, and matching selected keywords with resume screening tools.

4.1.1 Plagiarism Detection Tools

There are two types of plagiarism detection tools: one that searches from the web or a relevant database (e.g. journal papers (iThenticate), class homework (Turnitin)) to match the result, and the other that finds similarity between two documents. To find potentially useful software tools, assessment of 15 commercial software were investigated. Texts excerpted from Construction Owners Association of Alberta (COAA)'s best practices and distortions of them, accuracy of software performance was tested (Table 1).

Table 1. Example used for plagiarism detection tools

Text A (Original Text from an institution): "It is recognized that the use of illicit drugs and the inappropriate use of alcohol and prescription and non-prescription drugs can have serious adverse effects on a person's health, safety and job performance. A solid industry-wide model, including both a policy and guidelines, will help to enhance the level of health and safety at the workplace."
Text B (Distorted text version from Text A): "The use of illegal drugs and the unsuitable use of alcohol and prescription and non-prescription drugs can have severe hostile effects on a person's well-being, safety and job performance. A solid model, including both rules and guidelines, will help to improve the level of health and safety at the workplace."

Among the 15 software tools, eight different ones were evaluated, as they were either free or offered free trials. Among them, five offered plagiarism detectors browsing the web or databases, two offered text comparison, and one offered both.

The best plagiarism detector was PlagScan. It found the original source from the web computing 98.8% as plagiarized. Even when the distorted version of the excerpt was entered, it was still able to identify the original version computing 71.8% as plagiarized. According to PlagScan, the plagiarism percentage should be less than 5%. SmallSEOTools also found the exact source of the original text estimating 100% as plagiarized; however, estimated 0% as plagiarized for the distorted version and could not the find original source. Duplichecker, QueText and Plagium were not able to identify the right source; thus, estimated 0% as plagiarized.

Next, comparison between *Text A* and *Text B* was drawn. Copyscape was the best software in terms of comparing two texts resulting 75%, 83% matching. The reason for two values is because the total numbers of words in *Text A* and *Text B* are different. Table 2 provides the results. However, Copyscape is limited to word matching. It does not understand semantics within the context. Plagium estimated 40.8% as plagiarized. Interesting part of Plagium is that it provided sentence plagiarism as well as paragraph and page plagiarism. Copyleaks estimated 16% as plagiarized only considering continuous words that are identical.

Table 2. Results for word matching (Source: Copyscape)

59 words, 75% matched	Matching word count	53 words, 83% matched
It is recognized that		
The use of	3 words	The use of
Illicit		Illegal
Drugs and the	3 words	Drugs and the
Inappropriate		unsuitable
Use of alcohol and prescription and non-prescription drugs can have	11 words	Use of alcohol and prescription and non-prescription drugs can have
Serious adverse		Severe hostile
Effects on a person	4 words	Effects on a person
Health,		Well-being
Safety and job performance. A solid	6 words	Safety and job performance. A solid
Industry-wide		
Model, including both	3 words	Model, including both
A policy		Rules
And guidelines, will help to	5 words	And guidelines, will help to
Enhance		Improve
The level of health and safety at the workplace	9 words	The level of health and safety at the workplace

Plagiarism detection tools can check conformance in construction management. Not only the original sources of documents can be found but copy and paste phrases may be detected. If two documents' matching level is higher than a threshold that has been set, conformance is no longer valid. Software that compare two sets of texts may be applied as well using same words or same sentence structures detecting techniques. By setting a threshold, conformance can be checked.

4.1.2 Wordcloud Generator

Wordcloud generator can count words included in a document. It can automatically remove stopwords. Stopwords are the words that do not have important meanings such as articles and prepositions. Frequency of words can be automatically detected and more frequently to less frequently used words can be recognized. However, this software cannot recognize synonyms nor read sentences by context. For example, 'environment' and 'environmental' are considered as two different words, and 'construction' that has two different meanings are counted as one word.

This software can be adopted to identify keywords. High frequency of words does not necessarily mean that those words are more important than others. However, it is useful to track all words at once after processing such as removing the stopwords. Once keywords or key phrases are identified, the existence of them can be an indicator among others to check the conformance. Figure 4 and Figure 5 are result screenshots for examples from Construction Extension to the PMBOK Guide section 3.1.11 Project Health, Safety, Security, and Environmental Management (HSSE) (Table 3).

Table 3. Example used for wordcloud generator

Text C: "Site security and controlled access are discussed for construction job sites. Employee health and wellness are introduced for construction personnel as these directly affect construction project risk and safety. Trends include virtual technology and environmental certifications. While HSSE is applicable to all industries, the unique hazards in construction projects intensify the need for additional measures. The Planning Process Group includes a proactive view of health, safety, and environmental policy compliance. In addition to employee health and site security, a comprehensive health, safety, and environmental management plan is developed to address specialized stakeholders, reporting requirements, documentation and record storage requirements, training, and additional government requirements."

For this paper, "wordclouds.com" was used.

Figure 4. Screenshot of wordcloud generator results (Wordcould.com)

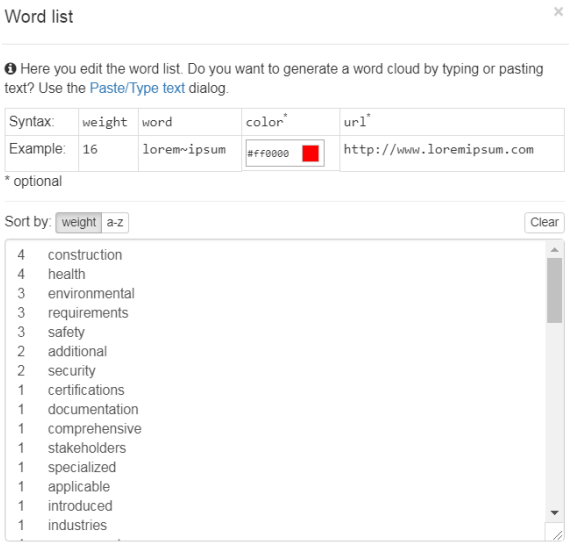

Figure 5. Wordlist from high frequency to low frequency (Wordcould.com)

4.1.3 Resume Screening Tools

Human Resources (HR) departments receive dozens of resumes a day. In order to reduce repetitive work, they use automated screening tools to match keywords they are looking for with candidates' resumes.

'Ideal.com' offers an artificial intelligence (AI) based recruiting system. Ideal's software can match keywords and can filter unqualified candidates. Powered by machine learning, next generation candidate screening software uses feedback from previous decisions. By using automated resume screening, HR can avoid skipping candidates who are competent. Candidates are screened and shortlisted instantly, so that HR knows whom to contact first.

By applying resume screening tools, comparing practice specifications with construction execution plans is feasible. If construction execution plans does not includes practice specifications, conformance cannot be achieved. With machine learning algorithms, conformance can be checked and data could be accumulated for the future usage.

4.2 Process Mining Tools

Process mining tools are for reconstructing workflows and representing them in formal process notation or iconography. They also can detect vulnerabilities automatically, analyze processing times, and detect bottlenecks. There are commercial process mining tools available such as Celonis, Disco, EDS, Fujitsu, Icaro, LANA, Minit, mylnvenio, Perceptive, and ProM. Once the process or workflow is discovered based on streamlined event logs, unrefined original event logs can be replayed or overlapped over the refined workflow, and conformance can be checked and deviations can be identified. By simply using filters, 'Disco' has allowed users to create process models. Pseudo case for Change Management was designed as illustrated in Figure 6. Case IDs, activities, and timestamps were entered and result is shown in Figure 7.

	Case Id	Activity	Timestamp
1	A-001	Initiated	2017/05/17 00:00:00
2	A-001	Modified	2017/05/30 00:00:00
3	A-001	Reviewed	2017/06/04 00:00:00
4	A-001	Approved	2017/06/11 00:00:00
5	A-002	Initiated	2017/06/20 00:00:00
6	A-002	Modified	2017/06/21 00:00:00
7	A-003	Initiated	2017/06/21 00:00:00
8	A-002	Reviewed	2017/06/22 00:00:00
9	A-002	Approved	2017/06/27 00:00:00
10	A-003	Reviewed	2017/06/30 00:00:00
11	A-004	Initiated	2017/07/01 00:00:00
12	A-005	Initiated	2017/07/01 00:00:00
13	A-005	Modified	2017/07/03 00:00:00
14	A-005	Approved	2017/07/05 00:00:00
15	A-006	Initiated	2017/07/05 00:00:00
16	A-004	Modified	2017/07/09 00:00:00
17	A-006	Rejected	2017/07/10 00:00:00
18	A-003	Approved	2017/07/26 00:00:00
19	A-004	Rejected	2017/08/03 00:00:00

Figure 6. Eventlog input (Disco)

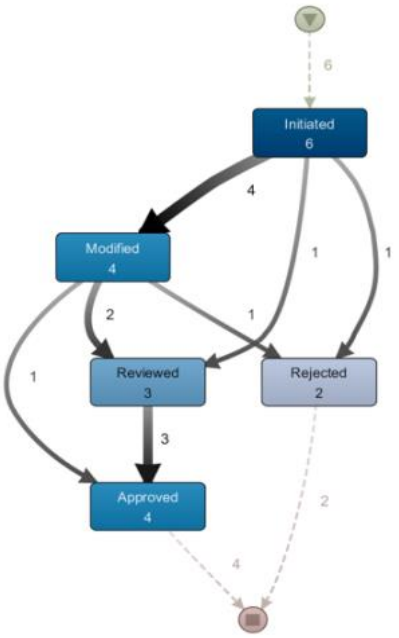

Figure 7. Result screenshot of process discovery (Disco)

LANAlab provides another software for process mining. It provides an academic version for free. LANA can discover a process model as well as develop a reference model. Figure 8 is the result screenshot of process discovery. For the input data, the same data that were used for Disco were entered (Figure 6).

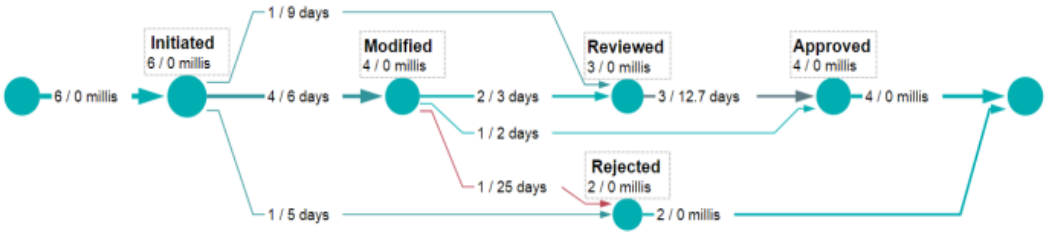

Figure 8. Process Discovery (LANA)

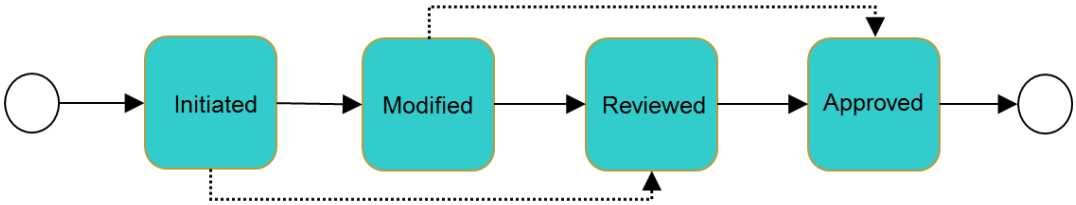

Figure 9. Reference Model in the Form of BPMN (LANA)

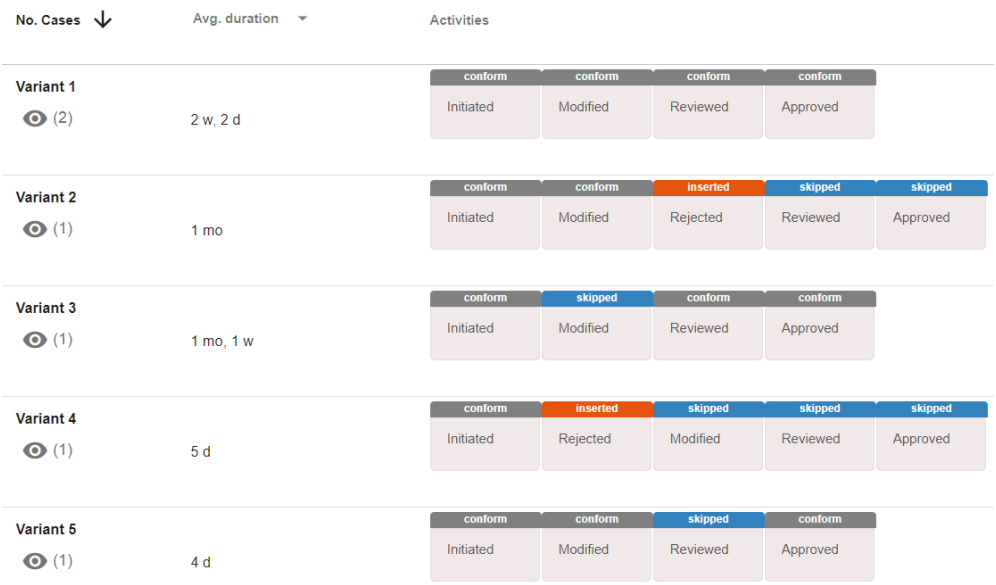

Figure 10. Variants Detected (LANA)

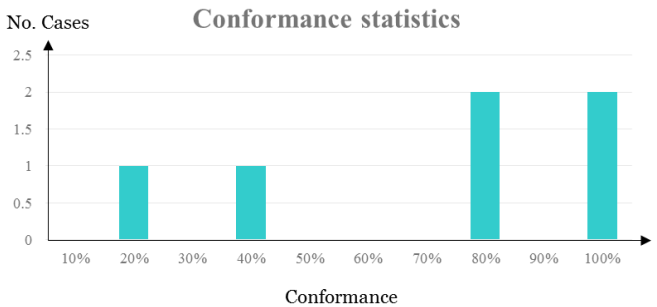

Figure 11. Conformance Statistics

The numbers in Figure 8 represent the number of cases and the average duration it takes. The reason why values are not assigned for activities is because only one representative timestamp has been entered for simplicity, and not start and finish. LANA is more advanced than Disco in terms of providing information. LANA also allows to develop reference model with process model. With the process model discovered from Figure 8, reference model was developed (Figure 9). Once the reference model was developed, variants were identified, and automated conformance checking became possible (Figure 10 and Figure 11). There are five different cases including one which is equivalent to the reference model. Conformance statistics computed how much each case conforms to the reference model. The x-axis of Figure 12 refers to conformance and the y-axis refers to number of cases.

Automated conformance checking tools from LANA can be useful for finding deviations from planned workflow. Planned workflow can be a reference model. Actual activities can be recorded in the form of event logs. These two can be automatically compared and checked.

4.3 Image Processing Tools

When communicating and implementing a good practice, images and/or photos may be included to facilitate understanding. With image processing tools, similarities or differences between two similar images or photos can be detected.

In this section, image search and image matching tools are introduced. Image search tools can browse the web to identify the original source of the image. Image matching can take place against a reference image. When it comes to conformance checking, image search tools can detect whether the query image is novel or not. Image matching tools can only be used conceptually yet because computers cannot understand the images to verify whether the images implies the same concept or not. Currently, only physical similarities or differences such as colors and shapes are detected. However, the importance is in the meaning and representation of images.

4.3.1 Image Search Tools

Image search tools are typically used for media intelligence, brand and/or copyright protection, and social media monitoring by browsing the web. It is composed of two key steps: indexation and retrieval.

The first step is to create a descriptor of the image content which can be referred as indexation. 'LTU Engine' suggests a visual signature for each image and describes its visual content with features such as color, shape, and texture. These descriptors are also called image DNAs. These image DNAs are then stored in a database. Retrieval is a special comparison technology by which an image signature can be compared at high speed with other image signatures from a database or the web for up to millions of images.

4.3.2 Image Matching Tools

LTU Engines' image matching tools use distinct pixel features to analyze visual content and identify matching images between a query image and references. Its image matching algorithm includes an optional matching zone parameter. The matching zone highlights where a query image matched with references. The matching zone details can be represented visually, as coordinates and as a percentage. The matching zone can be used to explain where and why two images matched.

4.4 Machine Learning

Machine learning can be adopted to all three types of AI software by receiving feedback from users or by learning autonomously, and learn to make better decisions. By retrieving results after checking the conformance, the computer can learn where conformance is maintained and where not. This information can be used for future conformance checking. Machine learning is often understood as data mining from a statistical point of view. It is partly because statistical cases have been solved more effectively with practical machine learning research.

5 Discussion and Conclusion

In this paper, artificial intelligence (AI) tools that can automate conformance checking have been evaluated. Although they cannot be the complete solution, there is potential for AI technology to be used as a basic toolset for aspect of conformance checking. By assisting construction management, this will not only save time and reduce human errors but also provide different perspectives and ways of checking the conformance. For future studies, more software, test cases, and data will be investigated as well as evaluated. Conformance will be measured and evaluated beyond just checking. Similarity of practice definition is necessary but not sufficient to ensure conformance. Implementation is most critical. Plagiarism algorithms can be used in various ways. However, they are challenged to identify lexical changes, structural changes and multi-sources. Wordcloud generator should apply more of features related to semantics. There are Process Mining software tools commercially available. However, as

most of them are not open source, only two software were tested. Acquiring proper event logs was also difficult. Image processing technology still has performance gaps to be used in conformance checking. Computers should be able to understand the images so that it can categorize them.

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