Automation in Construction 94 (2018) 22–38

Contents lists available at ScienceDirect

Automation in Construction

journal homepage: www.elsevier.com/locate/autcon

Construction automation: Research areas, industry concerns and suggestions for advancement

Qian Chen[a,*], Borja García de Soto[b,c], Bryan T. Adey[a]

[a] Institute of Construction and Infrastructure Management, ETH Zurich, Stefano-Franscini-Platz 5, Zurich 8093, Switzerland
[b] New York University Abu Dhabi (NYUAD), Saadiyat Island, Division of Engineering, Experimental Research Building, P.O. Box 129188, Abu Dhabi, United Arab Emirates
[c] New York University (NYU), Tandon School of Engineering, 6 MetroTech Center, Brooklyn, NY 11201, USA

ARTICLE INFO

Keywords:
Construction automation technologies
Cluster mapping
Text mining

ABSTRACT

Construction automation has shown the potential to increase construction productivity after years of technical development and experimenting in its field. Exactly how, and the possible benefits and challenges of construction automation, though is unclear and missing from current research efforts. In order to better understand the comprehensive potential of construction automation for increasing construction productivity and the associated possible ramifications, an objective and data-driven review of the use of automation technologies in construction was done. The review was accomplished by using text mining methods on publically available written documents, covering a wide range of relevant data including scientific publications and social media. The text mining software VOS Viewer and RapidMiner Studio were used to determine the most promising areas of research through the analysis of scientific publications, and the main areas of concern of industry through the analysis of text on social media, respectively. These research areas and concerns are summarized in this paper, and based on them suggestions for industry are made to help advance the uptake of automation in construction.

1. Introduction

The construction industry is falling behind others in terms of making productivity gains [1, 2]. One of the most promising ways to improve productivity is through the automation of parts of the construction process, which of course, can happen in many different ways, including the increased use of cross-functional teams in construction projects where emphasis is placed on learning and deploying the latest technologies, such as of the use of scrum techniques [3] or the use of robots to replace onsite labors [4, 5]. As many people both in research and in industry are working vigorously in the field of construction automation, a synthesis of their work and suggestions of where future efforts should be focused is of considerable interest to people trying to improve construction productivity.

One of the challenges of providing an overview of construction automation is that different people have different interpretations of what is meant with the words construction automation. For example, most designers consider it as a way to automate the planning and design of projects, but construction contractors consider it as the use of robots for onsite tasks. For example, some specialty construction contracting firms have developed prototypes of single-application robots (e.g., bridge painting robot, concrete blasting robot, rebar placement robot, fireproof coating robot and steel-skeleton welding robot, road maintenance robot) [6, 7]. Given different interpretations, a conventional literature review is difficult to conduct. First, the appropriate articles, or pieces of text, need to be found, and then they can be reviewed.

Finding the appropriate articles can be done using text mining methods for both the analysis of structured text [8, 9] (e.g. journal articles), and the analysis of unstructured text [10, 11], such as social media [12] (e.g., webpages of blogs and online news, podcasts (e.g., Twitter), web communities and blogs (e.g., Reddit Construction Blog), knowledge generating platforms (e.g., The Construction Index website), and web-based news (e.g., Construction News), among others). Text mining methods can be used to scour many different articles to obtain a general overview of the developments related to a specific topic, a scientific domain or a research area including the identification of patterns and relationships between new developments and, the tracking of how areas of strategic importance change over time [13]. Labonnote et al. [14], for example, used citation databases to identify journal publications with information that would be helpful in the investigation of the extent with which additive manufacturing technologies could be successfully applied to large-scale construction projects. Most of the

* Corresponding author.
E-mail addresses: chen@ibi.baug.ethz.ch (Q. Chen), garcia.de.soto@nyu.edu (B. García de Soto), adey@ibi.baug.ethz.ch (B.T. Adey).

https://doi.org/10.1016/j.autcon.2018.05.028
Received 8 December 2017; Received in revised form 19 May 2018; Accepted 28 May 2018

text mining analysis included the use of CiteSpace [15] and the Science of Science tool (Sci2) [16]. Khadjeh Nassirtoussi et al., [17], for example, used text mining on the major news webpages (e.g., webpage of Financial Times) to identify texts that would be helpful in the investigation of customer emotional sentiment preserved in the text to gauge the quality of market reception for a product.

The review presented in this paper was done by using VOS Viewer [18] and RapidMiner Studio [19] to identify the collected texts to investigate the developments in construction automation in research through the analysis of scientific publications, using text mining algorithms on Web of Science indexed journals (the journals shown in the Appendix Table 11), and text on social media from the websites (the websites shown in the Appendix Table 12), respectively. Based on the developments mentioned in these texts, suggestions were made as to how researchers and construction companies should focus their efforts to enable the construction industry to obtain maximum benefit from increasingly automating construction projects. The four steps used for both the analysis of the research publications and the social media were 1) determine exact research context, when starting with a general research context, 2) retrieve text, 3) assess data quality, and 4) model and visualize the patterns. With the analysis complete, the suggestions were made taking into consideration how the construction industry is most likely to benefit from increasing automation and how it might be hindered in developing in this direction.

2. Construction automation

Construction automation has many general definitions and different people see it at different levels of generality. For example, very generally a definition of “construction automation” was proposed by Bock [20] as a new set of technologies and processes that will change the whole course and idea of construction in a fundamental way. Jung et al. [21] used a more exact definition, referring to “construction automation” as a machine-centered construction factory technology for applying robotic systems on the construction field. A more limited definition was used by Vähä et al. [22] by describing “construction automation” as the automatic assembly method enabled by computer numerical control and real time sensing technologies. Skibniewski et al. [23, 24] used the term construction automation to principally mean the execution of construction tasks using robots. Their work showed that the automation of construction tasks requires substantial adjustments to the construction schedule and shifting of project recourses. Since the concept of Industry 4.0 has been introduced as a popular term for digitalization and automation of the manufacturing environment, the definition of construction automation has been extended to include information modelling and digitalization [25]. Some researchers argue that “construction automation” is the integration of computer-aided design and robot-based onsite technologies for simplification of overall activities [26]. A few of them, such as Willmann et al. [27], now use the term “digital fabrication” to as a synonym for “construction automation”, particularly when referring to customized building construction. The definition used in the work presented in this paper in the search for new developments in the field of “construction automation” was the use of technologies younger than 20 years in the design and construction processes with the goal of improving construction productivity.

3. Text mining processes

Text mining processes for structured and unstructured text are different. Structured texts, such as journal publications have a clear abstract, introduction and conclusions, and contain lists of keywords, whereas unstructured texts, such as though found on social media do not. Although numerous software packages for text mining exist, and they all use the same analyzing process, some are more useful for analyzing structured texts and others for unstructured texts. In this work, VOS Viewer, was used for the structured text analysis and RapidMiner Studio was used for the analysis of unstructured texts. VOS Viewer is a computer software primarily used for creating, visualizing and exploring bibliometric maps of scientific publications. It is able to convert the publication information into a text corpus for statistical analysis of words. It can be used to analyze the citation relations between publications, collaboration relations between researchers and co-occurrence relations between scientific terms (i.e., words). The text mining process in VOS Viewer for the analysis of co-occurrence relations between scientific terms consists of using a word similarity function to output a graph with clusters of these words. RapidMiner Studio is computer software that allows to transform text into a format useable for operator processing, such as finding the words that appear together in at least a threshold ratio of occurrences [28]. The text mining process in RapidMiner Studio is usually customized using different operators, wherein the most basic operators include “process documents from files”, “convert numerical vectors into binomials”, “FP-growth” and “create association rules” [29].

Both of VOS Viewer and RapidMiner Studio analyze documents or text files with the same text mining algorithms (e.g., similarity functions) in order to construct and visualize the important words. They are equipped with similar text mining functions and steps, such as calculating the occurrence of a word or a word stem as the first step. Although the final outputs of the two software display in different forms, they both show the important words that are relevant to construction automation as well as their relatedness. The analytic results from VOS Viewer and RapidMiner can be compared.

Either for VOS Viewer or in RapidMiner Studio, the text mining processes consists of four steps (see Fig. 1), with detailed sub processes when using each of the two software to model and visualize patterns. The basic assumptions made in the analyses were: 1) The publications cited from the Web of Science database adequately indicate the developments in research, 2) The most popular and influential websites (i.e., top 50 websites determined by Feedspot [30]) used indicate the developments in practice, and 3) The basic sense of the term “construction automation”, has not significantly changed over within the last 20 years (Jan 1997 to May 2017).

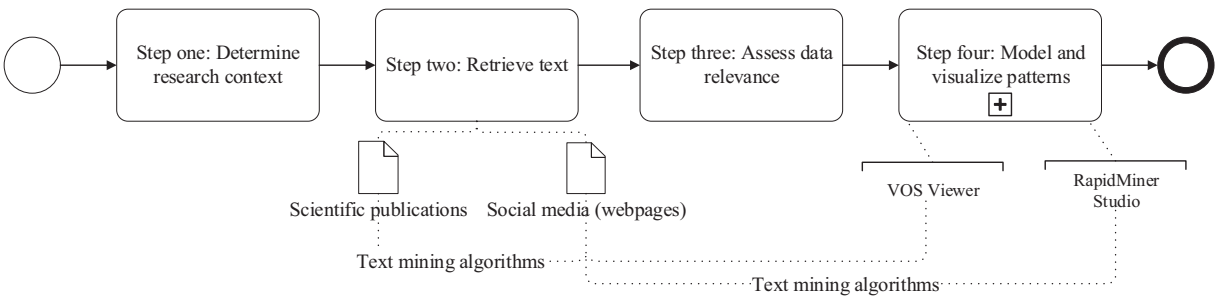

Fig. 1. Text mining process.