# Investigation of Bibliometric on the status quo of robotics in construction

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## Abstract

This study examines the current situation and degree of concentration in the field of construction robotics, which is fundamental to the automated construction industry in which robots do the majority of the monotonous and dangerous duties. A few robotic prototype construction-related strategies have been discussed. Data mining techniques were used to the 24,007 papers published in the years 2009 through 2019 in the Web of Science data repository. A thorough investigation of the frequency of computer-related phrases reveals a notable lack of attention to this field, particularly in the sector of building materials. The keywords that were investigated were chosen based on their level of relevance to the field of IT, computer science and robotics.

## Introduction

Robot is a machine that is design to excite the work automatically with speed and precision. With the introduction of Robotics technology in the construction industry it provides many advantages for companies and workers as it improves the efficiency of work, increases the productivity and tasks are done faster with the help of robots. Robots are also transforming the construction industry in a positive way with the dangerous and highly repetitive tasks being perished in the new technologies[1, 2]. There will also be less labour required using new robotic technologies which will help prevent injuries and casualties on site. In Australia, according to Safe Work Australia, construction is third in relation to work fatalities in the past 10 years. Recent studies show there has been 20 deaths in 2019 alone. With the help of new robotic technologies doing the hard and risky task there will be less injuries and deaths in construction. Project managers can also benefit from construction robotics by having a better over view of the project. A few examples of robotics which are already deployed in the construction industry will be discussed in the following sections. An automated construction industry would also allow the practicality of environmental urban development throughout the optimization of practices in terms of energy use, number of commutes, and waste generation [3, 4].

Results from the previous studies state that the construction managers do believe that one of the most important factors in enhancing the degree of productivity is the deployment of robots[5-7]. To achieve this, the construction firms need to have skilled employees in the field of IT and compute programing. A robot is essentially composed of two parts: software and hardware; each requiring different set of skills. Breaking down these two general skills into subcategories the following graph will be produced:

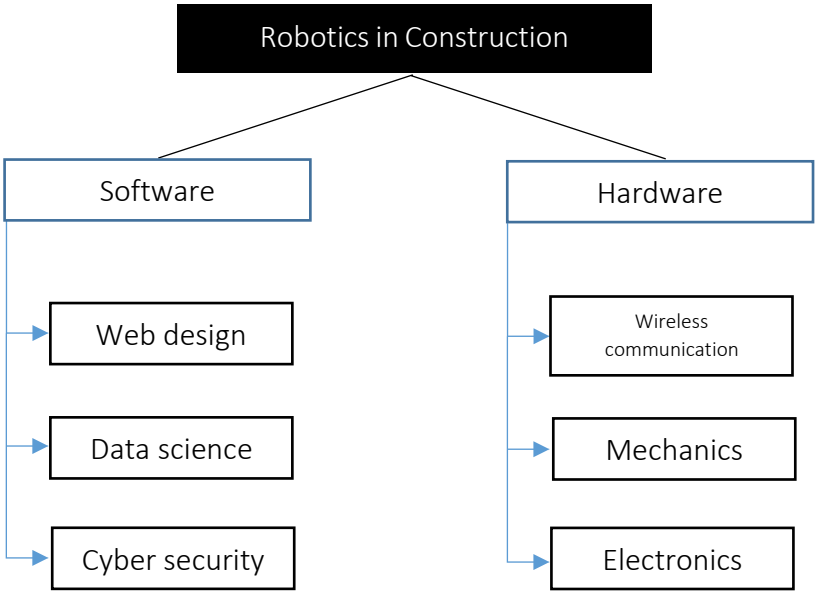


Figure 1 The components of robotics in the modern construction

In terms of software skills, the value of web design becomes significant once the trending international project delivery had gained attention. This allows communication of different sectors and contractors within a firm to be facilitated instantly whenever the extraction/access to data is needed[6, 8, 9]. Not only for international project delivery but even in the local level a web based communication system allows the faster and more accurate delivery of information to and from the construction site. Data science as the other important factor which requires more attention in the field, provides the foundation for prediction of the market direction. Data scientists are able to form and spread the data based on the existing data classification. To be more clear, data science is able to address the uncertainties based on the statistical models from the data obtained on the net. A well-established construction firm in the modern environment must be able to mine/extract a set of targeted data which would ultimately satisfy its objectives. Data after mining and processing will be sent via an established path to the consumer/contractor. It might be of special consideration in some cases that the access to data must be limited to a certain level of authorities inside a firm. The web service system is usually in such a way that the sender will deposit a set of data on a centralized server/pool and the receiver/consumer/contractor will request the server for data delivery. The server is normally available for public access. In such cases an encrypted data set will prohibit unauthorised consumers to gain access. Simply explaining, the encrypted data is stored in a locked package and the key is in the hand of the consumer.

From the hardware point of view, however, the story is relatively different. Data or software outputs are commands received by the actual machine. The relation between data and machine is similar to the relation between brain and muscle. Wireless communication routers are electronic devices that are sending and receiving data based on the voltage/current differences in the module. As the machineries in construction are playing an important role, the robotic arms are those which require a high level of knowledge in the mechanical domain. On the other side of the flip, since data is sent in the form of DC/AC voltage packages, a decent robot active in construction is a combination of mechanics and electronics. Thus it indicates the requirement for having electronic skills employed within the modern construction firm. Overall, the maintenance of construction machineries had always been a costly measure amongst others. Such skills can help reducing these costs as well[10-13].

Rebar-tying robots

With the introduction of rebar-tying robots work will be done faster than humans and reduce the cost. Rebar tying robot also known as Tybot is a new smart and advanced, developed robot that can identify every section of rebar on a bridge that can tie it and move to the next section. The robot can do almost of the work all that is required is for few workers is to place the rebar and oversee the root's progress. Rebar-tying is also a painful job for humans that have done rebar-tying and has led to strains and injuries from this type of construction work.

Automated demolition robots

One of the most dangerous job in construction is demolition work which has been proven unsafe. Things can happen unplanned like the structure collapsing, or causing damage to the

main services. Thankfully, one of the latest innovations in construction robotics that is used for demolition is the Husqvarna. The automated demolition robot can demolish entire building sites, as well as fit into small areas that construction workers often struggle to reach. The automated demolition robot is expected to worth around 320 million in 5 years. Automated demolition robot is a promising area of growth and an area of innovation that construction companies use in the future. Although the demolition robot can take time to bring in the demolition team to do it manually, however it can significantly reduce the risk of OH&S and cost which is a huge bonus for the construction industry.

Artificial intelligence for construction mapping

On site progress is one of the time consuming and hard job to monitor for construction managers specially if it's a big construction site. However, with the help of Doxel technology time tracking more efficient by using drones and rovers to map the construction sites every day, they then use the photos taken by the drone to compare it with the 3D drawings, BIM models and the project timeline to see if the project is in progress. From the data collected areas that are falling behind or different to the models can be identified so project managers can see the problem earlier and fix the defect and track the project timelines and is on the budget.

Bricklaying robots

Bricklaying robot is one of the latest promising innovation in construction also known as SAM (semi-Automated Mason). This bricklaying robot uses its mechanical arms, can pick up bricks, cover them with motor and lays each brick perfectly. The only thing that is required for the workers is to load the machine with brick and clean any extra mortar. The bricklaying robot (SAM) can lay between 300-400 bricks per hour, easily 5 times more than the workers who could roughly lay 60 to 75 bricks an hour, which shows there is more productivity and reduce budgets on projects. It can also free up workers' time to focus on more complex tasks the are better done with humans.

3D printing robots

Another technology that is having a huge effect is the 3D printing which is used for design and architectures. A mobile robotic arm controls the 3D printer and sets the program through instruction. The first 3D printed bridge was built in Netherlands and there are also other 3D robots the can build an entire building that's structurally safe. With the continuous improvement of new robotic technologies there will more and building built through automate building process which will improve the productivity of the project with less cost.

Welding arms

One of the most advanced technology that has been developed is robotic welding. The robotic welding uses its mechanised arms, welding positioners, and robot controllers to weld quickly and accurately. Robotic welding only requires only a few workers to oversee the work. With use of robotic welding there will be less risk of injuries and no need for man power to be used on manual tasks. With the help of robotic welding technology doing the task on its own, project teams can focus on more important task so they can meet the timelines, and managing the budget and ensuring productivity.

Autonomous construction machineries

Built robotics has developed a new bulldozer that self-drives during the earthworks. The self-driving bulldozer can automatically move piles of dirt from one destination to another without any supervision. The bulldozer uses its sensor and self-driving technology to grade earth on construction site without the help of any worker on site. This can help free up team to do the more important tasks that require more skill. The other studies also had emphasised on the benefits of utilizing automation in construction for extra-terrestrial applications [14] and had evaluated the gains achieved in managerial terms as well [15].

## Bibliometric Analysis

As a matter of the fact, the idea had always led by the scientific community followed by the technological advancements in the industry's practices. Bibliometric analysis outlines the status quo in the scientific community and it can be used to understand how far reaching the automated construction industry is. As a statistical method to analyse books, articles and other publications, these sort of analysis reveal various set of information. The spectrum of famous scientific data bases expands to Scopus, Science Direct, Web of Science, Science Citation Index, Mendeley, Merck Index, Cochrane Library, and beyond. However, for the sake of this study data mining procedure had gone through the Web of Science data base. The following list of journals (Table 1) majoring the field of construction materials had been selected for evaluation. The publication period ranges from 2009-2019 although in the instance of Construction and Building Materials journal due to the high volume of publications in that period we have limited the period to 2014-2019 in order to limit the effect and influence of this journal on the final results.

Table 1 List of the selected top ranked journals majoring in construction materials indexed in the Web of Science data base.

| No. | Name of the journal | Publication year | Number of articles |
|---|---|---|---|
| 1 | Cement and concrete research | 2009-2019 | 1,964 |
| 2 | Building and environment | 2009-2019 | 4,265 |
| 3 | Journal of Composites for construction | 2009-2019 | 974 |
| 4 | Construction and building materials | 2014-2019 | 11,779 |
| 5 | Automation in Construction | 2009-2019 | 1,944 |
| 6 | Journal of Materials in Civil engineering | 2009-2019 | 3,081 |
| | | Total | 24,007 |

Model 1

Titles and abstract had only gone under the analysis. Minimum number of occurrence of a term had been limited to 200. From the total of 279,247 terms, 513 met the threshold. For each of the 513 terms, a relevance score was calculated. Based on this score, the most relevant terms were selected. The default choice is to select the 60% most relevant terms. Out the 513 terms identified, 250 top results were selected.

From the total of 250 terms investigated in terms of occurrence in the construction related literature only the following list has some sort of relevance to IT and computer science:

Table 2 List of the terms with more than 250 occurrence relative to the IT and computer science field.

| Term | Occurrence | Term | Occurrence |
|---|---|---|---|
| Algorithm | 786 | Numerical model | 350 |
| BIM | 335 | Numerical result | 224 |
| Calculation | 492 | Numerical simulation | 432 |
| Data | 3532 | Sensor | 443 |
| Information | 1206 | Simulation | 1475 |
| Analytical model | 291 | Simulation result | 302 |

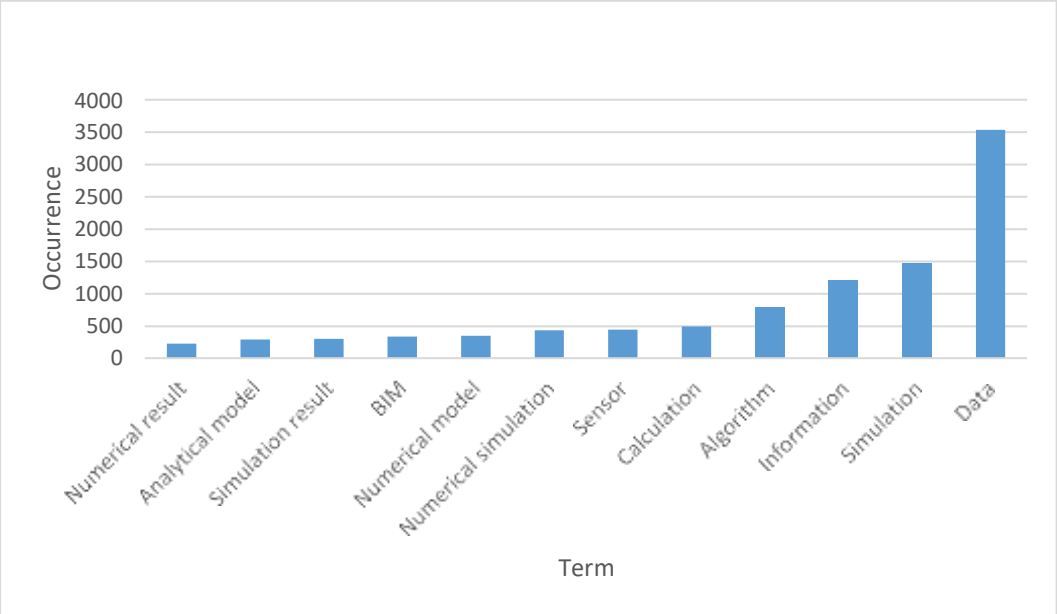


Figure 2 The distribution of IT and computer science relevant terms based on the occurrence in the first model

From the above it can be derived that only 4.8% of the terms are relevant to IT and computer science indicating the huge gap between construction industry and the possibility of embracing robotics in construction.

Model 2

Minimum number of occurrence of a term had been limited to 100. From the total of 279,247 terms, 1024 met the threshold. For each of the 1024 terms, a relevance score was calculated. Based on this score, the most relevant terms were selected. The default choice is to select the 60% most relevant terms. Out the 1024 terms identified, 500 top results were selected.

Table 3 List of the terms with more than 100 occurrence relative to the IT and computer science field.

| Term | Occurrence | Term | Occurrence |
|---|---|---|---|
| Algorithm | 786 | Numerical model | 350 |
| BIM | 335 | Numerical result | 224 |

| | | | |
|---|---|---|---|
| Calculation | 492 | Numerical simulation | 432 |
| Data | 3532 | Sensor | 443 |
| Information | 1206 | Simulation | 1475 |
| Analytical model | 291 | Simulation result | 302 |
| Artificial Neural Network | 143 | Computational fluid dynamic | 249 |
| Building information management | 116 | Database | 394 |
| CFD simulation | 127 | Modelling | 413 |
| Monitoring | 512 | Software | 372 |
| Digital image correlation | 116 | Finite element | 206 |
| Finite element analysis | 174 | Finite element model | 223 |

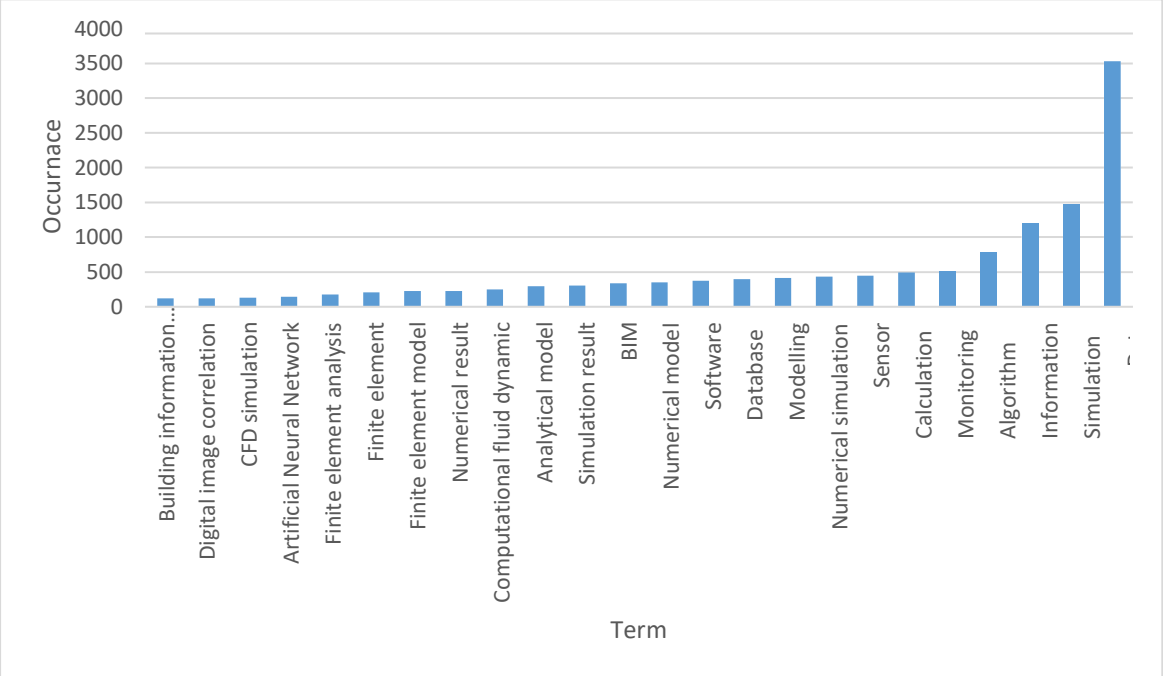


Figure 3 The distribution of IT and computer science relevant terms based on the occurrence in the second model

From the above it can be derived that only 4.4% of the terms are relevant to IT and computer science indicating the huge gap between construction industry and the possibility of embracing robotics in construction.

## Conclusion

In both of the bibliometric models run on less than 5% of the terms were relevant to the domain of IT and computer science. It is an indication for the low level of focus on robotics in construction. More dividing the construction economy into two sectors, education and industry, the education sector is urged to implement more IT related course in the course syllabus. This will ensure that the fresh graduates who are trained to be employed are skilled enough to bring more automation. On the other side, the construction industry sector must

put more emphasis on employing computer programmers and robotic experts in order to appreciate the principles of automation.

## Acknowledgement

This research could not be accomplished by the facilitation of Western Sydney University technical staff members, supervisors and fellow academics. Special thank goes to the Graduate Research School of Western Sydney University for regulating and providing the necessaries required for the accomplishments of this paper. Western Sydney University library staff had fantastic contribution in the data collection procedure. The contribution of Institute of Construction Materials (ICONSMAT) had also shed light on the alignment of this research.

## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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