Progression of Human Experience Integration in the Construction Industry

Cyril Ahiable and Abdul-Aziz Banawi(✉)

Department of Construction Management and Engineering,
North Dakota State University, Fargo, ND 58105, USA
{Cyril.Ahiable,Abdulaziz.Banawi}@ndsu.edu

Abstract. The construction industry is known to be particularly dependent on human involvement. Construction projects are usually unique and filled with varying degrees of uncertainties. These uncertainties pose risks that can be detrimental to the project's success. Human cognition and decision making are vital in surmounting these risks adequately. The quality of cognition and decision-making comes from the extensive experience of architectural, engineering and construction (AEC) professionals on different construction projects and processes. There have been various innovations developed to improve construction processes from design to construction. There have also been attempts to integrate this valuable human experience with available technologies to improve efficiency and eventually achieve desired levels of automation. This paper explores the various strides taken in integrating human experience with available construction technologies. The conclusion of this study examines the successes and failures in all endeavors concerning human experience integration in design, materials, safety, constructability, and other areas involved in the construction process.

Keywords: Cognition · Human experience · Integration · Construction

1 Introduction

Construction industry requires significant amounts of communication and collaboration between the parties involved. The architects, engineers, project managers, supervisors etc. must be in constant communication for the project to be delivered efficiently. Over the years, technology has advanced in improving collaboration and communication in construction through the introduction and application of Building information modelling (BIM), Artificial Intelligence (AI) and other developments. These innovations have improved the construction workflow to some acceptable extent but there is certainly more room for improvement. One aspect that is lagging is the integration of human experience with these available technologies. If we agree that construction is heavily dependent on human involvement, one can argue that the quality of human experience is vital to the construction process. Human experience however is not the easiest type of data to integrate with computing. This is primarily due to its predominantly qualitative nature which requires substantial coding in order to be assimilated and implemented by computers. Human experience in construction has been collected

J. Charytonowicz et al. (Eds.): AHFE 2021, LNNS 272, pp. 45–50, 2021.
https://doi.org/10.1007/978-3-030-80710-8_6

through interviews, surveys, and direct observation but the challenge with this type of data is its scalability and spatial interpretation. This means every information of this sort requires significant time and energy and can be hardly generalized or iterated. For integration of human experience with modern technology, we need a systematic scalable feedback process which can be efficiently interpreted and executed in the computing world [1]. Despite the challenges involved in integration of data such as human experience, attempts have been made over time to achieve such a purpose. This paper makes a broad exploratory effort to analyze all attempts in integrating human experience with technologies in the construction industry.

2 Progression of Human Experience Integration in the Construction Industry

According to [2], human experience/expertise stems from the self-acquisition of skills and capabilities to improve one's effectiveness in defining an external reality. Sociologists for a long time have worked in understanding the entirety of the concept of human expertise. [3] supports the above definition by adding that human expertise provides the self-governing human with the knowledge to delineate, control and adapt to various possible events within their professional scope. The study of human expertise set the stage for enquiries into other possible forms of expertise and their possible usefulness in the grand scheme of improving human abilities. [4] on his work on expert systems initiated the development of "expert systems" which are simply rule-based computing programs designed to out-perform humans in terms of decision making and problem solving. The introduction of this idea was a good basis for the development of more sophisticated technologies in achieving this goal. [5] in comparing these expert systems with human expertise discovered a challenge these expert systems have. The limitation of these expert systems is in the fact that they are rule-based. The uniqueness of human expertise is the ability to rely on prior knowledge and adapt to relatively new real time situations. These expert systems can only perform within the confines of the algorithms upon which they were built.

[6] in his piece on "construction expertise and posthumanism" provided fictional examples on how these expert systems fall-short of actual human expertise on construction projects. One example explained how an automated brick-laying machine may not be able to discern the adequate textures and gradients outside the command fed into it while a human expert can adapt and make the necessary adjustments per the conditions present. A look at the timeline of the progression of human experience integration shows a steady increasing trend of the incorporation of three main apparatus: Expert Systems, Building Information Modelling (BIM) and machine learning. Eventually, BIM became all-encompassing as the idea of expert systems slowly disappeared. Since the introduction of expert systems by Feigenbaum, 1992, [7] sought to improve on this concept by introducing techniques to aid these expert systems minimize delays through efficient scheduling. The study created a model called the Isolated Delay Type (IDT) which can be used individually or integrated with Computerized Delay Claims Analysis (CDCA) systems. [8], developed a multi-attribute model with the Delphi technique which sought to improve the selection of procurement systems.

This was another variant of the integration of human expertise with systems in the construction industry. The study found that the Delphi technique was useful in detecting the right procurement system objectively. Another instance was the integration of human expertise for subcontractor selection by [9]. In this study, a knowledge based expert system was implemented to create a user-friendly interface for subcontractor selection. With time, BIM became more popular and integrated all these separate expert systems through add-ons and plugins. The evolution of BIM alone illustrates a steady attempt in integrating human expertise with construction computing software. BIM alone is still predominantly dependent on human manipulation and is not necessarily an independent decision-making process. Experts have begun to explore the extents of other technologies like machine-learning with deep learning and neural networks.

The human being has an insurmountable ability to apply general knowledge in problem-solving situations for specific cases. Where human ability falls short is in the analysis of large numbers of scenarios occurring simultaneously [10]. This is where computers fortunately come in where they excel in a process called induction which involves the use of machine learning to produce decision rules from prior decision examples. Currently, the application of machine learning is largely in constructability analysis, safety, and material property prediction. This has been achieved by coding a large amount of human expertise data into software programs to be applied on the field. [11] looked at the application of machine learning in injury prediction on construction projects. The study made significant progress in providing reliable probabilistic predictions on injury severity and outcomes of accidents on construction projects. [12] examined the integration of human expertise with machine learning technology to predict the compressive strength of materials and concluded that high levels of accuracy were achieved with the combination of neural networks and support vector machines (SVM's). The timeline in the following figure was created to summarize the progression of attempts in integrating human expertise in construction based on the reviewed articles (Fig. 1).

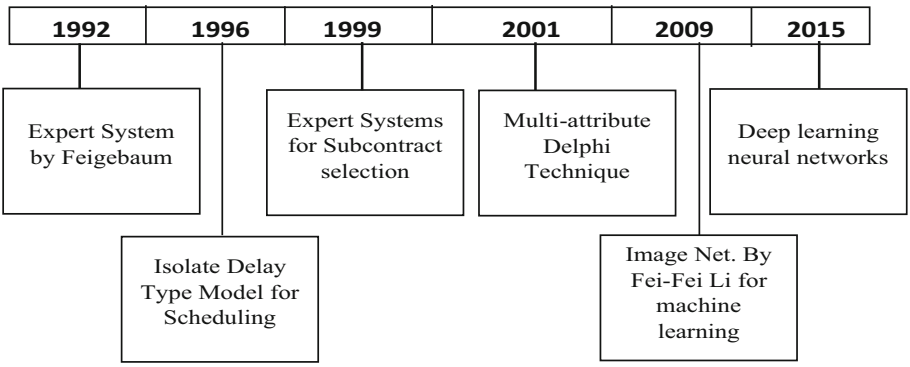

Fig. 1. Timeline of the milestone attempts at integrating human expertise in construction.

3 Methodology

This study adopted a predominantly meta-synthetic approach where multiple qualitative research studies were evaluated, and findings interpreted based on the subject of human experience integration in construction. This method was adopted because it fits the general inductive approach best suited for the type of data collected in this study (Fig. 2).

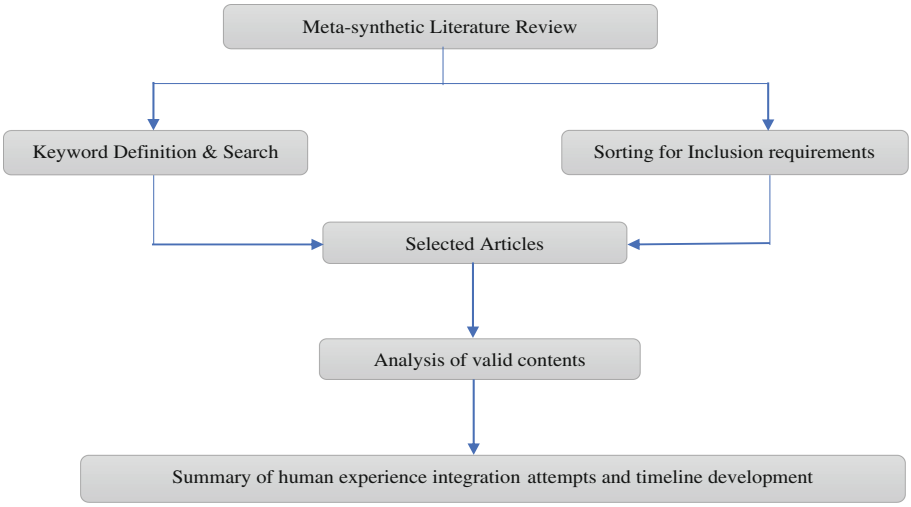

Fig. 2. Schematic representation of research methodology.

An inductive approach requires the condensation of raw textual data into summaries and establishing links between the evaluations and research objectives. Since this paper focuses on reviewing a broad range of prior work concerned with human experience and construction, the inductive research method with meta-synthesis was appropriate. Owing to the relative rarity of literature on this subject, the search was not limited to a specific period in order with the earliest selected study dating as far back as 1991. This was to ensure an exhaustive review process. Giving this, the requirements to qualify an article for selection were: 1. The articles must be peer reviewed, 2. The articles must contain specifics on human experience and construction 3. The selected articles should highlight methods attempted for the integration of human expertise in construction. The words “experience” and “expertise” were used interchangeably in the search string to ensure potentially all-inclusive search results. A timeline was designed to summarize the reviewed information for clearer perspective on the progression of human expertise integration. The chart below summarizes the search, selection and analysis process.

4 Results and Discussion

The review of all the works concerned with human expertise integration into construction only exposes the vast room for improvement. As it stands, all the methods have a common limitation: the versatility of the models developed. Most of the models created only cater for a tiny niche within an aspect of the construction process. Of course, this is a step in the right direction and with the rapid development of machine learning tools, we can hope for a more all-inclusive model that can closely mimic human expertise especially in discerning and decision making. It is highly impossible to achieve a fully autonomous construction industry due to the level of diversity and variations of risks spread across locations and trades in construction. From the timeline diagram, it can be realized that the most recent milestone in the integration of human expertise in construction was in 2015 with the emergence of advanced deep learning neural networks in machine learning. Currently, it seems that machine learning is where experts want to achieve substantial human expertise integration. The potential for this exists but not much progress has been achieved outside the vein of predicting construction outcomes. The perfection of predictability software can be further developed to incorporate automatic decision making to bring computers closer in mimicking human decision making.

5 Conclusion

Human expertise in construction is an asset of immense value and hence the efforts to integrate this significant data source with technologies in the industry must be lauded. Clearly, the emergence of machine learning has boosted the potential of significant human expertise integration. The integration of human experience in construction only serves to drastically reduce risks on project sites, improve decision making and improve overall efficiency of the construction process. It will be a challenging feat to achieve but with the rapid rate at which artificial intelligence and machine learning are being improved, we can hope to see such levels of integration in the foreseeable future. For now, human expertise remains at the core of the success of construction projects, but we must aim to lighten this burden by improving available technologies to mimic human abilities like decision making and adaptability.

References

1. Pyke, C., McMahon, S., Dietsche, T., U.S. Green Building Council: Green building & human experience. USGBC research program white paper (2010)
2. Eyal, G.: For a sociology of expertise: the social origins of the autism epidemic. Am. J. Sociol. **118**(4), 863–907 (2013)
3. Friedson, E.: Professionalism: The Third Logic. PolityPress, Cambridge (2001)
4. Feigenbaum, E.: A Personal View of Expert Systems: Looking Back and Looking Ahead, Report No. KSL 92-41, Knowledge Systems Laboratory, Stanford University, Stanford, CA (1992). https://goo.gl/Nk5Xgc. Accessed 28 Aug 2015

5. Dreyfus, H., Dreyfus, S.: Expertise in real world contexts. Organ. Stud. **26**(5), 779–792 (2005)
6. Sage, D.J.: Rethinking construction expertise with posthumanism. Constr. Manag. Econ. **34** (7–8), 446–457 (2016)
7. Alkass, S., Mazerolle, M., Harris, F.: Construction delay analysis techniques. Constr. Manag. Econ. **14**, 375–394 (1996)
8. Chan, A., Yung, E., Lam, P., Tam, C., Cheung, S.: Application of Delphi method in selection of procurement systems for construction projects. Constr. Manag. Econ. **19**, 699–718 (2001)
9. Okoroh, M., Torrance, V.: A model for subcontractor selection in construction projects. Constr. Manag. Econ. **17**, 315–327 (1999)
10. Arciszewski, T., Rossman, L. (eds.): Knowledge Acquisition in Civil Engineering. ASCE, New York (1992)
11. Tixier, A.J.P., Hallowell, M.R., Rajagopalan, B., Bowman, D.: Application of machine learning to construction injury prediction. Autom. Constr. **69**, 102–114 (2016)
12. Erdal, H.: Contribution of machine learning methods to the construction industry: prediction of compressive strength. Pamukkale Üniversitesi Mühendislik Bilimleri Dergisi **21**(3), 109–114 (2015)