ICCEPM 2022
The 9th International Conference on Construction Engineering and Project Management
Jun. 20-23, 2022, Las Vegas, NV, USA

A Summary of History and Evolution of Project Management Tools towards Reinforcement-Learning-based Technologies

Arnold Jan Bitangjol[1*], Kanghyeok Lee[2], Jungeun Hwang[3], Do Hyoung Shin[4]

[1]*Graduate Student, Program in Smart City Engineering, Inha University, Incheon 22212, South Korea,* E-mail address: *arnoldjan.bitangjol@gmail.com*

[2]*Senior Researcher, The Research Institute of Construction & Environmental System, Inha University, Incheon 22212, South Korea,* E-mail address: *kanghyeok@inha.ac.kr*

[3]*Graduate Student, Program in Smart City Engineering, Inha University, Incheon 22212, South Korea,* E-mail address: *h.jungeuning@gmail.com*

[4]*Corresponding Author, Professor, Department of Civil Engineering, Inha University, Incheon 22212, South Korea,* E-mail address: *dshin@inha.ac.kr*

Keywords: History, Project Management, Project Management Tools, Reinforcement Learning

1. INTRODUCTION

Project management (PM) has been practiced for thousands of years tracing back all the way to the times of ancient Egypt during the construction of the Pyramid of Giza (2250 BCE) or in China when the Great Wall was built (221-206 BCE). Subsequently, project management has been evolving and has been very much driven by external factors such as war and economic forces where there have been business pressures to organize resources and meet end goals [1]. As project management evolves so as the methodologies and tools that accompanies it follow suit. The study of [2,3] identified four periods in the history of project management and the corresponding project management tools (PMT) and technologies used in each period. In the study of [3] the four periods were identified as (1) prior to 1958, (2) 1958 – 1979, (3) 1980 – 1994, and (4) 1995 – to 2006. In these four periods project management tools have evolved from using craft systems to utilizing a wide variety of computer software.

In recent years, the availability of PMT in the market is rapidly increasing and these have significantly evolved so that project managers use them in planning, monitoring and control projects [4]. However, although automated PMT are useful, they are general purpose in nature and require additional capabilities to access full management control [5]. Therefore, to tackle the mentioned deficiencies, Artificial Intelligence (AI) such as Machine Learning (ML) techniques are adopted to aid project managers to easily delegate thousands of tasks, while keeping a complete view of their resources and projects [6]. One type of ML used in project management is reinforcement learning (RL) [7]. And with reinforcement learning, we now come to the fourth period described in [3] as *Creating New Environment*, where there were at least 11 studies identified between the years 2004 to 2018 regarding RL applications for solving project management problems, and 22 studies between the years 1997 to 2018 presenting RL applications to production management problems [7].

The objective of this study is to review and facilitate an understanding of the evolution of project management tools through analyzing its origin, periods of evolution, significant impact to project management methodologies, and perceiving the potential direction to where this evolution will further advance.

2. FOUR PERIODS OF PROJECT MANAGEMENT

The study of [3] divided history of project management into four as shown in Table 1. In the first period, the study asserts that project management first evolved from the first use of conventional method such as Parametric cost estimation, PERT/CPM, and Gantt chart to the progress of significant technological advancement of computer leading to the change in dynamics of construction management. This change defined the second period of project management, where computer technology developments made the application of management science flourish. These computers were further developed and made personal computers (PC) widely available making project management techniques more accessible [3]. Thus, shifting people to use multitasking computers and software tools such as Primavera [2,3] and MS Project [8] that further evolved to web-based software and has become widely available in the fourth period. The advancement in the fourth period became more progressive with computer software enabling project managers to navigate transactions through various web-based software and platforms with a wide selection of productivity features resulting in more efficient work and project management.

Table 1. Four Periods of Project Management *(Kwak, 2003)*

Period	Significant Evolution	Technology
Before 1958	Craft system transformed to Human Relations Administration	Parametric Cost Estimating PERT/CPM Gantt Chart Monte Carlo Simulation Systematic Application
1958 to 1979	Application of Management Science	PMI Inventory Control Material Requirement Planning
1980 to 1994	Human Resources became the center of production following the availability of PC	Matrix organization PM Software for PC • Primavera (1983) • MS Project (1984) • Artemis View (1992)
1995 to 2006	New Environments are created	PMBOK (PMI) BaseCamp (1999) GanttProject (2003) Redmine (2006)

The study of [9] identified software project management tools that are capable of process planning, organizing, staffing, monitoring, and controlling projects. For example, BaseCamp is a web-based application tool that can be accessed through a web browser and the internet. It allows more than one project and provides storage to projects [9,10]. It includes features such as milestone view, activity view, completed task view, calendar view, integrated messaging system, and time tracking. However, this software cannot assign specific deadlines so users will have the tendency to forget to add time, add later, or even change. Consequently, the development of the software GanttProject, comes with more features such as Work Breakdown Structure (WBS), and resource management. Moreover, GanttProject is made as a cross-platform tool, so it is compatible and runs in Windows, Linux, and Mac OS operating systems [2,8,9]. Redmine, however, has even a few more features that include task identification, issue tracking, news, document and file management, time tracking, per project and wiki forms.

However, these software project management tools are generic in nature. Although these project management tools are useful, they need sophisticated and additional capabilities to be under full management and solve specific, complex problems such as resource-constrained scheduling problems. Thus, creating a new era through artificial intelligence (AI), including the adoption of reinforcement learning (RL) in project management.

3. ADOPTION OF REINFORCEMENT LEARNING IN PROJECT MANAGEMENT

Since Software PMT has limitations and can be generic in nature, Artificial Intelligence (AI) are adopted. One example of AI widely used today is Machine Learning that is further categorized in three types [10]: (1) supervised learning (SL), (2) unsupervised learning (UL), and (3) reinforcement learning (RL).

The study of [11] analyzed both supervised and unsupervised learning in predicting construction crew productivity. Results showed that SL has been proven successful in predicting construction crew productivity. Meanwhile, other applications correlating with causal relation between input and output having complex variability, learning task is often easier with UL. It was further noted that both SL and UL are proved to be precise but slow [12]. Conversely, [13] asserted that because RL does not require any prior knowledge of the workload or the system model it can learn the policy with real-time incoming tasks and adjusts the policy accordingly. Further, simulation results proved that it could achieve better power performance trade-off than other existing expert-based power management algorithms.

SL makes predictions based on a set of labeled data while UL does not require labeling. SL is often costly and not time-efficient working with large and complex data therefore UL is a better option. However, RL does not require data in advance; instead, the learning agent interacts with an environment and learns the optimal policy based on the feedback it receives from that environment. Thus, RL demonstrates impressive performance in wide range of applications including games, robotics, and control [10]. The following are applications of RL in project management identified in [3]. Shown in Table 2 are the project management problems solved using specific RL applications.

In resource constrained project scheduling problems (RCPSP), RL is used to find an optimum "*makespan"*, which is defined as a feasible schedule within a minimum time which all jobs are

completed considering a specific *m* jobs and *n* resources [14,21]. Similarly, problems such as RCPSP and multi-project RCPSP (MRCPSP) can also be solved through Agent-based approaches (A-Team) [16,19,23]. A-Team is a system composed of multiple optimization agents, management agents, and common memories which through interactions leads to more effective use of the available resources and reduce computation time. Furthermore, the odea of an A-Team was to develop a software environment called JADE-based A-Team (JABAT) [23]. The JABAT environment has been proven successful in solving different NP-hard optimization problems, vehicle routing problems, clustering problems, and resource availability cost problems. The proposed method of Padberg [15] and Padberg et. Al [17] found the optimal scheduling using RL optimization-based simulation technique. The simulation derives optimal polices that assigns tasks according to past performances. Results indicated that simulation can be applied in optimization to save computational time of estimating tasks.

Table 2. RL Algorithms used in Project

Problems	**Solution**
RCPSP [14][19][18]	Rout algorithm of RL with SVM
MRCPSP [15][16][17][18][20]	Multi-agent RL strategies
	A-team multi-agent system
	Learning automata
Multi-skill RCPSP [21]	TLBO

Using RL, each project manager learns their activity list and specifically learns automata. Results shown that the application of this scheme improves the goal of minimizing project delays. RL has also observed to be beneficial in solving decentralized resource-constrained multi-project scheduling problem [19] and Multi-skill RCPSP [22]. In the study of [19], metaheuristic search is strengthened by using RL while in [22] multi-skill resource constrained project scheduling problem (Multi-skill RCPSP) is treated with teaching-learning-based optimization algorithm (TLBO).

Studies in RL have been used widely in management problems in relation to resources, activity schedules to reduce time, selection of activity predecessors, etc., but not as much for risk-related project management problems. Consequently, a potential study of RL solving risk-related project management problems can be an interesting direction to further advance the scope of RL in project management.

4. CONCLUSIONS

In this paper, we review the four periods of the evolution of project management where resources, politics, economics, and significant historical events are key factors of these changes.

The evolution of these tools is driven to deliver better efficiency and productivity in project management while the dynamics in the environment are changing and have resulted in more complex problems.

From the first use of conventional tools the evolution pivoted in the development of Gantt Chart, PERT/CPM, and Monte Carlo Simulation. In further evolution, these previous developments are

carried out in a variety of software-based project management tools such as Primavera and MS project which both use Gantt Chart, PERT/CPM, and perform estimations through Monte Carlo Simulation. This further resulted to various more innovations, wide availability of software in the market, and hence another period of evolution.

However, while these new innovations have proven successful in carrying out project management objectives with new and different key features there were limitations that need to be resolved. As a result, the adoption of artificial intelligence created a new era. Artificial intelligence such as machine learning has become more widely used because of their robust capability in solving project management problems. Specifically, reinforcement learning uses an algorithmic agent to optimize results making it a good tool to maximize resources and optimize project cost and duration.

Therefore, a potential study of RL solving risk-related project management problems can be an interesting direction to further advance the scope of RL in project management.

In conclusion, the identification of these tools will help us understand how these developments are used to solve a specific problem within a given unique situation, the rationale of their creation, and in what direction these innovations can be further advanced.

ACKNOWLEDGEMENT

The support of the "National R&D Project for Smart Construction Technology (No.22SMIP-A158708-03)" funded by the Korea Agency for Infrastructure Technology Advancement under the Ministry of Land, Infrastructure and Transport, and managed by the Korea Express Corporation is gratefully acknowledged.

REFERENCES

[1] Jones, C. (2004). Software project management practices: Failure versus success. CrossTalk: The Journal of Defense Software Engineering, 17(10), 5-9.

[2] Cicibas, H., Unal, O., & Demir, K. A. (2010, July). A Comparison of Project Management Software Tools (PMST). In Software Engineering Research and Practice (pp. 560-565).

[3] Koulinas, G., Xanthopoulos, A., Kiatipis, A., & Koulouriotis, D. (2018, September). A summary of using reinforcement learning strategies for treating project and production management problems. In 2018 Thirteenth International Conference on Digital Information Management (ICDIM) (pp. 33-38). IEEE.

[4] Mishra, A., & Mishra, D. (2013). Software project management tools: a brief comparative view. ACM SIGSOFT Software Engineering Notes, 38(3), 1-4.

[5] Sajad, M., Sadiq, M., Naveed, K., & Iqbal, M. S. (2016). Software Project Management: Tools assessment, Comparison, and suggestions for future development. International Journal of Computer Science and Network Security (IJCSNS), 16(1), 31.

[6] Kozak-Holland, M. (2011). *The History of Project Management (Lessons from History)*. Lakefield, Ontario, Canada: Multi-Media Publications, Inc.

[7] Pinnacle Management Systems, Inc. (2009, June 2). *Primavera Product History*. https://www.pinnaclemanagement.com/blog/primavera-product-history

[8] IEREK Admin. (2016, February 1). *Primavera Origin and Development.* IEREK. https://www.ierek.com/news/index.php/2016/02/01/primavera-origin-and-development/

[9] Kanakaris, N., Karacapilidis, N. I., & Lazanas, A. (2019). On the Advancement of Project Management through a Flexible Integration of Machine Learning and Operations Research Tools. In ICORES (pp. 362-369).

[10] Ayodele, T. O. (2010). Types of machine learning algorithms. New advances in machine learning, 3, 19-48.

[11] Miller, K. (2017, April 4). *What is Microsoft Project? A Quick History*. workzone. https://www.projectmanager.com/blog/what-is-microsoft-project

[12] Keup, M. (2020, March 3). *What is Microsoft Project? Uses, Features and Pricing.* Projectmanager. https://www.projectmanager.com/blog/what-is-microsoft-project

[13] Gersmann, K., & Hammer, B. (2004, July). A reinforcement learning algorithm to improve scheduling search heuristics with the svm. In 2004 IEEE International Joint Conference on Neural Networks (IEEE Cat. No. 04CH37541) (Vol. 3, pp. 1811-1816). IEEE.

[14] Gersmann, K., & Hammer, B. (2005). Improving iterative repair strategies for scheduling with the SVM. Neurocomputing, 63, 271-292.

[15] Padberg, F. (2005, July). On the potential of process simulation in software project schedule optimization. In 29th Annual International Computer Software and Applications Conference (COMPSAC'05) (Vol. 2, pp. 127-130). IEEE.

[16] Wauters, T., Verbeeck, K., Berghe, G. V., & De Causmaecker, P. (2011). Learning agents for the multi-mode project scheduling problem. Journal of the operational research society, 62(2), 281-290.

[17] Jędrzejowicz, P., & Ratajczak-Ropel, E. (2017, June). Reinforcement learning strategy for solving the MRCPSP by a team of agents. In International Conference on Intelligent Decision Technologies (pp. 537-548). Springer, Cham.

[18] Ratajczak-Ropel, E. (2018). Experimental evaluation of agent-based approaches to solving multi-mode resource-constrained project scheduling problem. Cybernetics and Systems, 49(5-6), 296-316.

[19] Padberg, F. (2005, July). On the potential of process simulation in software project schedule optimization. In 29th Annual International Computer Software and Applications Conference (COMPSAC'05) (Vol. 2, pp. 127-130). IEEE.

[20] Padberg, F., & Weiss, D. (2011, December). Optimal scheduling of software projects using reinforcement learning. In 2011 18th Asia-Pacific Software Engineering Conference (pp. 9-16). IEEE. [21] Zheng, H. Y., Wang, L., & Zheng, X. L. (2017). Teaching–learning-based optimization algorithm for multi-skill resource constrained project scheduling problem. Soft Computing, 21(6), 1537-1548.

[23] Ratajczak-Ropel, E. (2018). Experimental evaluation of agent-based approaches to solving multi-mode resource-constrained project scheduling problem. Cybernetics and Systems, 49(5-6), 296-316.

[24] Li, H. (2020, December 9). *Which machine learning should I use?* The SAS Data Science Blog. https://blogs.sas.com/content/subconsciousmusings/2020/12/09/machine-learning-algorithm-use/

[25] Oral, M., Oral, E. L., & Aydın, A. (2012). Supervised vs. unsupervised learning for construction crew productivity prediction. *Automation in Construction*, *22*, 271-276.

[26] Nick, W., Shelton, J., Asamene, K., & Esterline, A. C. (2015). A Study of Supervised Machine Learning Techniques for Structural Health Monitoring. *MAICS*, *1353*, 36.

[27] Shen, H., Tan, Y., Lu, J., Wu, Q., & Qiu, Q. (2013). Achieving autonomous power management using reinforcement learning. ACM Transactions on Design Automation of Electronic Systems (TODAES), 18(2), 1-32.