Research Assessment Exercise 2020
Impact Case Study

University: City University of Hong Kong
Unit of Assessment (UoA): 13 - computer studies/science (incl. information technology)
Title of case study: AI research for automatically scheduling engineering works for Hong Kong MTR

(1) Summary of the impact

Dr. Chun's research on AI was used to develop an advanced AI system for automatically scheduling engineering works for MTR, replacing an inefficient manual process. The AI system has a direct positive impact on MTR, improving staff productivity by automating scheduling and dispatching, and improving maintenance efficiency by 50%, allowing more works to be performed within the limited maintenance window. The AI system is one of the key factors contributing to MTR's 99.9% on-time performance, which benefits 5 million passengers per day. The AI system has won several awards and has been featured in news articles throughout the world.

(2) Underpinning research

Dr. Andy HW Chun joined the Department of Computer Science of City University of Hong Kong in 2001. Prior to that, he was in the EE Department in City University of Hong Kong from 1995 to 2001. From 2009-2015, he also served as the Chief Information Officer (CIO) for City University of Hong Kong. For his innovative use of technology for higher education, he received the Hong Kong CIO Award as well as the China Top 5 CIO Award. He also has extensive experience in startup operations, and has founded several technology companies.

From the early 1990s onward, one of Dr. Chun's research interests has been on resource allocation, scheduling and planning using artificial intelligence (AI). In the early 90s, Dr. Chun has researched and developed the first AI system commercially deployed in the HK airport, which optimized airport gate management, aircraft ground movements, stand allocation [1], and cargo handling [2]. Specifically, constraint-programming was used to assign parking stands to aircraft and schedule towing movements to satisfy the business logic [1]. In late 90s, Dr. Chun developed the world's first pure-Java AI constraint programming engine, called JSolver, soon after the Java language was first released. JSolver eventually became part of what is now IBM Watson's Decision Optimization suite.

In early 2000, Dr. Chun began research on applying AI for optimizing, managing, and planning for railway systems, in particular Hong Kong's MTR. In 2004, he first conducted research on an AI rule-based system for automatic conflict-checking of engineering works [3], where the knowledge representation and rule system was designed based on safety regulations and government statutory requirements, as well as operational guidelines. This initial AI system only validated the proposed engineering works as safe to execute. Based on this initial research, in 2005, Dr. Chun proposed an AI system [4] for automatically scheduling engineering works in order to maximize the number of jobs that can be performed within the maintenance window, while also adhering to all the constraints, rules and regulations. The scheduling system is based on genetic algorithm and heuristic search, which work together with the rule-based system. An interactive scheduler was also proposed, which allows the user to manually change part of the schedule and the AI system will automatically repair the schedule. In 2013, Dr. Chun proposed an AI system for scheduling train outstabling [5], which concerns the parking of trains in the rail network during non-traffic hours so that they are close to their starting points for the next day, and do not interfere with the engineering works at night. This problem was formulated as a constraint satisfaction problem (CSP), and then

solved using a two-stage search algorithm. Finally in 2014, the research from the past 10 years culminated into a complete AI system for scheduling, resource management, outstabling, and rule checking [6]. In this work, the scheduling algorithm was changed into a CSP that was solved using a two-phase algorithm, and a more scalable knowledge schema was designed to allow for growth in the rail network.

(3) References to the research

[1] Chun AHW, Chan SHC, Tsang FMF, Yeung DWM. "Stand-allocation system (SAS): a constraint-based system developed with software components", *AI Magazine* 21 (4), 63-74, 2000.

[2] Fok K, Ka M, Chun, AHW. "Optimizing Air Cargo Loading Planning and Analysis", In *Proceedings of the International Conference on Computing, Communication and Control Technologies*, Aug 2004.

[3] Chun HW and Yeung WM, "Rule-based approach to the validation of subway engineering work allocation plans." In *Intl. Conf. on Computing, Communications, and Control Technologies*, 2004.

[4] Chun HW, Yeung WM, Lam PS, Lai D, Keefe R, Lam J, Chan H (2005). "Scheduling Engineering Works for the MTR corporation in Hong Kong". In *17th Conf on Innovative Applications of Artificial Intelligence (IAAI-05)*, Pittsburgh, July 2005.

[5] Chun HW. "Train Outstable Scheduling as a Constraint Satisfaction." In *25th Conf on Innovative Applications of Artificial Intelligence (IAAI-13)*, Bellevue, Washington, July 2013

[6] Chun HW and Suen TYT. "Engineering Works Scheduling for Hong Kong's Rail Network" In *26th Conf on Innovative Applications of Artificial Intelligence (IAAI-14)*, Quebec City, July 2014.

(4) Details of the impact

Context

In Hong Kong, MTR operates 10 subway lines and light rails, consisting of 152 stations. Maintaining high-quality 99.9% on-time reliable service requires well-maintained lines. Each week 2,600 engineering works are required on the railways, involving 10,000 maintenance personnel. Since the maintenance window is only 4-5 hours each night, the scheduling of engineering works is an important task where maximally utilizing the time window can improve efficiency. Scheduling is a complex problem, and in the past was performed using a time-consuming manual process, requiring managers to simultaneously consider many facets, such as resource allocation, conflict resolution, rules and government regulations, and safety standards. The complexity increases as MTR is actively expanding by adding new lines and stations. Thus, the old manual procedure was not efficient and not scalable.

In 2011, MTR contracted Dr. Chun to research and develop an AI system for automatically scheduling maintenance works as described in Section 2 and [6]. Research was conducted between 2011 and 2013. The AI system was soft-launched for testing in May 2013, and refined and updated by Dr. Chun until the final handover to MTR in July 2014. The AI system has been continuously used since then.

Impact to MTR and HK

The AI system has a direct positive impact on MTR: 1) the automated scheduling enhances staff productivity -- several person-days of effort are saved each week that were previously required for manual planning [6], and the automatic dispatching of engineering works saves 30 minutes per night compared to manual dispatching [6]; 2) the AI system yields a productivity gain of about US$1 million annually [B]; 3) MTR has obtained an improvement of over 50% in maintenance efficiency by using the AI system [C]; 4) AI conflict and rule checking has ensured that railway safety rules for engineering works are complied with [A]. Furthermore, the scalable design of the AI system has been shown to be effective: since 2014, three new line extensions have been added to the MTR network without any problems.

Finally, the AI system is a key factor enabling MTR's 99.9% on-time performance, which benefits 5 million passengers per day. Without efficient scheduling of maintenance works by the AI system, it would not be possible to maintain such a high performance – there would be difficulty to schedule enough engineering works into the maintenance window at night, and such perpetual delays and backlogs of maintenance works could eventually lead to system degradation and service delays or disruptions. In summary, the outcomes of this project have a positive impact on MTR's operations, improving staff productivity and maintenance efficiency, and supporting HK railways' continuous growth, which ultimately benefits millions of HK citizens and visitors with a highly reliable on-time public transportation system.

Reach & Significance

The AI system is a unique technology developed for and adopted by MTR, which no other railway in the world possesses. Because of its significance, the system has been reported in popular press throughout the world. In 2014, *New Scientist*, the world's most popular weekly science and technology magazine, ran an article on the AI system and its impact to MTR [B]. The *New Scientist* article was picked up by *Curbed New York* [D], *Popular Mechanics* [E], and *Washington Post* [F], as an example of how advanced technology used in MTR could also improve subway systems in New York City and Washington DC, and by *Huffington Post* [G], *CNN* [H], *World News Stand*, *Time Out HK* and *Sourceable*, in which the benefits of AI in business operations were discussed. The article was also picked up by a few non-English news sources, such as *Il Post* (Italy, April 27, 2017) and *El Espanol* (Venezuela, Sep 26, 2015). In 2015, another article discussing the role of AI in rail systems was published in *DataConomy* [C], which is a news portal with expert opinions on data-driven technologies.

The AI scheduler has won several awards and recognition in local and international communities. In 2014, CityU, MTR, and PCCW jointly won the *Best Business Solution Grand Award* and the *Best Business Solution (Application) Gold Award* for their integrated system for engineering works management, of which the AI scheduler is a key component. In 2017, *AI Magazine* (published by AAAI) listed the AI system as one of the top-10 high-impact AI applications over the past 30 years [J]. These articles and awards demonstrate that the AI system has far-reaching impact as a success case of using AI in a business application, inspiring others to follow.

(5) Sources to corroborate the impact

[A] Ted Suen. Letter of support from MTR. Sep 15, 2019.

[B] Hal Hodson. "The AI boss that deploys Hong Kong's subway engineers", *NewScientist*, July 2, 2014. https://www.newscientist.com/article/mg22329764-000-the-ai-boss-that-deploys-hong-kongs-subway-engineers/

[C] Bhoopathi Rapolu (2015). “Bringing Artificial Intelligence to the Rail Industry”, *Dataconomy*, https://dataconomy.com/2015/11/bringing-artificial-intelligence-to-the-rail-industry/

[D] Patrick Sisson, “What NYC’s subway system can learn from ones around the world”, *CURBED New York*, 29 Sept 2017. https://ny.curbed.com/2017/9/19/16335068/nyc-subway-mta-state-of-emergency-solution

[E] Adam Hadhazy, “5 Technologies could save the New York Subway”, *Popular Mechanics*, 27 Oct 2014, https://www.popularmechanics.com/technology/infrastructure/g1653/5-technologies-that-could-save-the-new-york-subway/

[F] Frederick Kunkle, “If Metro had an artificial brain, maybe it wouldn’t be so dangerous”, *Washington Post*, 10 Aug 2016. https://www.washingtonpost.com/news/tripping/wp/2016/08/10/if-metro-had-an-artificial-brain-maybe-it-wouldnt-be-so-dangerous/

[G] Thomas Tamblyn, “Artificial Intelligence is Already Controlling Humans”, *Huffington Post UK*, 7 July 2014. https://www.huffingtonpost.co.uk/2014/07/04/artificial-intelligence-human-control_n_5557724.html

[H] Maggie Hiufu Wong. “HK’s MTR: Taking a ride on the world’s most envied metro system”, *CNN*, 31 March 2015. https://www.cnn.com/travel/article/hong-kong-mtr-success-story/index.html

[I] 2014 Hong Kong ICT Award for Best Business Application (Grand Award and Gold Prize). http://www.hkcs.org.hk/ictawards/2014/english/winners.html

[J] Smith, R. G., & Eckroth, J. “Building AI Applications: Yesterday, Today, and Tomorrow.” *AI Magazine*, 38(1), 6-22, 2017. https://www.aaai.org/ojs/index.php/aimagazine/article/view/2709