An alternative way to smart construction

By Dr Wilson Lu, The University of Hong Kong

The slow development of AI in construction

Recent years have witnessed a resurgence of interest in artificial intelligent (AI) and robotics, normally putting under the common nomenclature of “smart construction”. According to Kurzweil et al. (1990), AI is “the art of creating machines that perform functions that require intelligence when performed by people”, while robotics can be perceived as a branch of AI development. As an academic discipline, AI began in the 1950s and has experienced a winding development. Compared to the omnipotent image of AI seen in science fiction, e.g. the Terminator, or the lovely Wall E, some stunning breakthroughs more relevant to our daily life have been newly achieved. For example, in a 2011 game of Jeopardy, IBM’s Watson supercomputer as AI defeated the game’s two highest ever grossing champions. While in 2017, the AI program AlphaGo defeated the world’s grandmasters of the ancient Chinese game, Go. Many industries from Wall Street trading to manufacturing are examining the threats and opportunities brought by AI and robotics.

Construction is no exception. Unlike the stereotype that construction is slow in embracing new technologies, the sector is strenuously exploring AI and robotics, with a view to making construction a safer, greener, and a more productive workplace. Robotic systems have been developed for assisting special on-site construction tasks such as automatic laying of tiles (Westkamper et al. 2000), automatic fabrication of building structures on site (Khoshnevis 2004), and helping workers to handle heavy materials (Lee et al., 2006). Local contractors are reported to be developing robots for curtain wall installation or other onerous tasks. Nevertheless, despite the continuously growing interests in robotics and smart construction, few applications can actually reach the implementation stage, let alone put into daily operation in construction. There is widespread frustration in the industry in respect of AI and robotics applications in construction.

The explanations are manifold. First, construction components are particularly heavy, not lending themselves to be easily handled by any robots. They are not like “sowing shoes or clothes”. An extreme example is the immersed tube tunnel elements in the recently completed Hong Kong-Zhuhai-Macau bridge. A single element is as heavy as 6000 tons. To lift and install it is a world-class challenge in its own right, no matter what robots one imagines. Another reason lies in the
heterogeneous and fragmented nature of construction. When robotic arms and automation systems are applied to the manufacturing industry, where identical products are made in a fixed production line, they can function effectively and efficiently by following standard and repeating workflows. In contrast, every construction project is unique and faces incessant variations each day. An applicable robot on a construction site must cope with the complexity of adaptively changing construction process, making it impossible to directly transplant the mature manufacturing robotic systems into construction. Thirdly, too often, existing smart construction solutions emphasize the adaption of the existing working environment or procedures to accommodate new technologies rather than the other way around. For example, research and investment is being put into the development of mobile platforms, manipulators, and advanced control systems on construction sites in order to cater for the operation of robots (Zied 2007). Likewise, robot oriented design (ROD) has been proposed as a strategy for reengineering conventional construction processes and redesigning construction details in a way that facilitates the implementation of construction robots (Bock 2007). However, the radical changes caused by these fundamental process redesigns can be intrusive and sometimes interruptive to workers accustomed to traditional construction workflows, thus attenuating their inclination to accept the new technologies (Liu et al. 2018).

At the University of Hong Kong, a research team specialized in smart construction are developing an interesting and clever approach called “smart construction objects (SCOs)”. Instead of continuously inventing and bringing in new artifacts for construction personnel to learn, SCO aims to find an alternative way of achieving smart construction by making existing construction resources and objects smarter. Similar to many existing technologies, SCO makes full use of existing smart technologies, such as Building Information Modeling (BIM), Internet of Things (IoTs), robotics, sensing, computing, automation, big data analytics, and machine learning in the construction context. What is particularly unique is it advances less disruptive ways of introducing these technologies into the existing construction practice in order to minimize changes to established work routines. The team encapsulates the concept under the title of “i-Core” and won a prestigious Construction Industry Council (CIC) Innovation Award 2015.

**Smart construction object (SCO) and i-Core**

SCOs are defined as construction resources that are made “smart” by augmenting them with smart properties. Here the construction resources could be machinery, tools, device, materials, components, and even temporary or permanent structures. The core smart properties of SCOs are awareness, communicativeness, and autonomy. Awareness denotes the ability of SCOs to sense and log their real-time condition and that of the surrounding vicinity. Communicativeness denotes the ability to output information, e.g. via ad-hoc networking obtained through its awareness. Autonomy refers to the ability to take self-directed action or alert people of necessary further action based on preset rules. Whilst these SCOs demonstrate intelligence similar to that found in some existing robotic systems, what makes them different is SCOs’ capacity to maintain the traditional functions and appearance of the construction recourses they rely on. For example, a smart excavator may be able to locate and report

Awardees (first row) with judges and the then Chief Executive of Hong Kong, Leung Chun-ying in the Government House (second row)
its real-time position without demanding extra room while still performing the excavation job.

It is particularly challenging to customize “smartness” into real-life construction practices that are often procedure-specific, project-specific, and company-specific. Therefore, the research team developed the i-Core prototype to innovatively encapsulate the smartness. i-Core denotes a standalone, programmable, and extensible integrated chip that can be implanted to construction machinery, devices, and materials. Similar to a central processing unit (CPU) of a computer, i-Core turns dead-weight construction components and plants into SCOs and makes smart construction possible. Various modules can be integrated into i-Core in order to meet the changing needs on construction sites and achieve different functions. These modules are extensible, which can be customized case by case.

Case scenarios
With strong support from the Hong Kong Housing Authority, Gammon Construction and their suppliers, the research team has explored and tested SCOs with the underlying i-Core prototype. i-Cores are embedded or attached to a few chosen construction components and machines to make them into SCOs, facilitating the process in logistics and supply chain management (LSCM), occupational health and safety (OHS) management, productivity management, etc.

Smart prefabricated components
By making prefabricated components into SCOs, the research team developed an SCO-enabled management platform to facilitate logistics and supply chain management in prefabrication housing production. An i-Core prototype has been developed with the ability to sense its real-time location and synchronize the location data to the web-based user interface (Figure 3). A Global Positioning System (GPS) tracker and a GSM (Global System for Mobile Communication) module with respective antennas have been integrated into i-Core to enable the real-time sensing and communicating abilities. Each i-Core is incorporated into a black box design, which can be embedded in the surface recess of a prefabricated component when loaded for shipping. Thus, damage can be avoided during loading and unloading, while the black box can be demounted for reuse. The hole left after removal of the black box can be filled with concrete when the component is assembled.

When a prefabricated component is embedded with i-Core, it becomes a SCO. Each SCO is assigned a unique identification code associated with the basic design parameters. When linked to Google Maps, the real-time position of each SCO can be simultaneously plotted on the interactive map. The BIM has also been incorporated in the online user interface. The delivery status of each SCO can be indicated in the BIM. Different colors indicate different status of SCOs, such as ‘in production,’ ‘delivering,’ ‘arrived,’ etc. When SCOs enter into the predefined areas, the component color in the BIM will be automatically changed without manual input.

Smart tower cranes
Making tower cranes into SCOs could enable the real-time monitoring and control of crane operations, while the data captured by the smart tower crane could further facilitate data analysis in OHS management and productivity management. To make a tower crane into a SCO, the research team developed a series of i-Cores, each consisting of a microcontroller, an inertial measurement unit (IMU), a GPS module, a barometer, a tensometer, an anemometer, and a GSM module. These i-Cores were mounted to the key components of an on-site tower crane, including the jib, the trolley, and the
The user interface with BIM and an interactive map

Hoist of Beam B1-46 (14:00:07-14:07:11, 7 Nov. 2016)

The user interface with BIM and data visualization modules
In this way, smart construction can be achieved with autonomy capabilities captured within i-Core. More intelligent via the awareness, communicativeness, functionalities of construction objects, but to make them ‘disruptive technology,’ SCO aims not to alter the existing thus more realistic than ‘full’ AI. Unlike the advocacy of decisions can be made by SCOs autonomously. It is the process, although some routine or clearly rule-based SCO keeps humans in the knowledge loop and active in consciously aware of. Unlike the advocacy of ‘full’ AI, that both practitioners and researchers might not be SCO as an alternative model of smart construction enabling a safer, greener, more efficient, and effective these challenges, it is envisaged that SCOs will gradually supersede traditional construction objects to become the basic elements of construction in the future, thus enabling a safer, greener, more efficient, and effective construction industry than has been seen before.

**Theoretical contribution, challenges and prospects**

While indeed the research team is accepting collaborations from the industry to further develop SCO-based solutions, the purpose of this article is to highlight SCO as an alternative model of smart construction that both practitioners and researchers might not be consciously aware of. Unlike the advocacy of ‘full’ AI, SCO keeps humans in the knowledge loop and active in the process, although some routine or clearly rule-based decisions can be made by SCOs autonomously. It is thus more realistic than ‘full’ AI. Unlike the advocacy of ‘disruptive technology,’ SCO aims not to alter the existing functionalities of construction objects, but to make them more intelligent via the awareness, communicativeness, and autonomy capabilities captured within i-Core. In this way, smart construction can be achieved with minimal interference in existing construction processes and such solutions can be more easily accepted by frontline construction personnel. It aligns with the argument that a successful smart construction system is one that causes the least interruption to accepted processes (Niu et al. 2016). Unlike the advocacy of developing a complex, powerful, and centralized AI system, SCO-enabled smart construction is decentralized to the specific construction tasks so it, similar to the IoTs, can increase the responsiveness to the challenge of the construction tasks. In so doing it can also deal with the aforementioned heterogeneity and fragmentation of construction by extending or customizing its smart properties.

SCOs, with their core smart properties, present a new vision for future smart construction. Given the fact that SCOs are in the early days of their development, there are technical hurdles, e.g. on-site locating for awareness, ad-hoc networking for communicativeness, machine learning algorithm for autonomy, and interoperability and robustness of the technologies, making SCOs yet to be widely applicable in current construction practices. In addition to the hurdles, there are other non-technical challenges, in particular, the acceptance of AI, organization readiness, cultural changes, and the new cost to be overcome. Nevertheless, by overcoming these challenges, it is envisaged that SCOs will gradually supersede traditional construction objects to become the basic elements of construction in the future, thus enabling a safer, greener, more efficient, and effective construction industry than has been seen before.

**About the author**

Dr Wilson Lu is based in the Department of Real Estate and Construction, Faculty of Architecture at the University of Hong Kong. His research interests include BIM, smart construction, big data in construction waste management, and international construction. Email: wilsonlu@hku.hk, Tel: (852) 2859 7981.

References

- Kurzweil, R (2010). The Singularity is Near. Gerald Duckworth & Co