Autonomous Robotics in the AEC practice

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In recent years, technical development in robotics has been enhanced by leaps forward in artificial intelligence and machine learning (ML). Today's robots learn and optimize their motion, are remotely connected and ready for deployment, and can transfer learned models and behaviors between industries or applications.[1] This paradigm shift and step change in available autonomy necessitates rethinking how robotics may impact the AEC industry.

Until now, contractors and fabricators have mainly used robots to replace humans in the narrow opportunity presented by "Dull, Dirty, and Dangerous" tasks (the 3Ds)—repeated millions of times with little variability. However, AEC professionals are starting to explore robots' ability to perform tasks that are "Specific, Sustainable, and Scalable" (the 3Ss). Robots complete specific tasks by producing one-off designs and sustainable tasks as they render viable reuse as well as material and waste reduction. Yet they maintain scalability by being able to effortlessly multiply into the hundreds or even millions. They are "smart" enough to work alongside humans, rather than replace them.

What Is the Current State of Robots in the AEC Sector?

This review presents robotic applications and emerging ideas with potential in the AEC industry and allied disciplines through products that explore specificity of tasks, sustainable workflows, and scalable designs. The presented examples intend to identify development directions without actual validation of the feasibility of these pursuits. The overview organizes the discussion around three themes: autonomous tasks, robots as tools extending human faculties, and enhanced entire workflows.

Towards Autonomous Tasks

Perhaps the most successfully marketed AEC robot is Boston Dynamics' SPOT, an agile robot used on construction sites for data capture (i.e., monitoring progress and health and safety).[2] SPOT is a quadruped which allows the robot to navigate complex environments, traversing stairs, cluttered areas, or uneven terrain. Once it has memorized a teleoperated journey, it is able to repeat this route while automatically maneuvering around obstacles. Commercial construction firms including Swinerton[3] of San Francisco and Pepper Construction[4] of Chicago have pioneered the use of SPOT in the industry. At the end of 2020, there were 400 SPOT robots deployed across multiple industries.[5]

Beyond SPOT, several robotics startups are working in collaboration with contractors on a variety of nontrivial challenges. For example, Dusty Robotics' FieldPrinter,[6] developed with DPR Construction[7] is a BIM driven, automated layout robot that can accurately and quickly print full-size floorplans onto the floor so workers can build directly off the plan and thus reduce errors.

BuilderX,[8] in partnership with worksite equipment manufacturers XCMG,[9] has developed a way to remotely operate mining equipment, and supports semiautonomous tasks such as loading trucks, levelling land, or digging agricultural canals. BuilderX has demonstrated commercial viability[10] in mining and is now transferring this experience to the construction of the Sichuan-Tibet high-speed railway.[11]

Meanwhile, Piaggio Fast Forward, in collaboration with the inventor of the iconic Vespa scooter, has developed gita, a "smart" trolley designed to follow its owner and carry their belongings. Gita aims to negotiate interaction with notoriously unpredictable humans.[12] While it is at present aimed at consumers, it could plausibly have applications in AEC settings, such as carrying tools for workers, thus reducing the need for on-site vehicles.

Chinese property developer Country Garden has teamed up[13] with Guangdong firm Bright Dream Robotics and, in May 2020, announced a number of single task robotics aimed at improving worker productivity. For example,[14] its Geko G100 robot navigates around sites following the BIM floor plan, then uses a grinding module on an adjustable arm to grind wall putty. It also comes with a vacuum to collect dust generated by the grinding.

Rebar configuration is a time-consuming task on building sites which involves using wire to tie together metal reinforcement bars. T-iROBO Rebar is an autonomous robot which is able to handle this task automatically. Developed by fuRo, at the Future Robotics Technology Center at Chiba Institute of Technology and Japan's Taisei Corporation,[15] the robot is intended to address the challenges of an aging workforce.

Sekisui House, Ltd. Japan's largest homebuilder, has joined forces with tmsuk robotics to develop Carry and Shot robots. These machines work autonomously and together to attach gypsum boards to ceilings.[16]

Tools Augmenting Humans

A number of robotic technologies look into extending human capabilities through automation or enhancing safety by making complex physical tasks easier.

For example, Norwegian firm nLink is collaborating with HILTI to create a robot that drills holes for ceiling anchors,[17] a task that is uncomfortable for humans and can cause pain and injury. The robot augments workers' abilities, enables complexity, and facilitates ergonomically challenging tasks.

Meanwhile, California's SuitX makes computer-controlled exoskeletons that aim to support health and safety as well as precision for construction workers (by, for instance, making it safer to lift heavy objects). The firm first started out designing for the medical market but is pivoting to service manufacturers, including Siemens and GM.[18]

Avoiding mistakes or augmenting and upskilling humans is the foundation of Shaper, the handheld CNC router now part of Germany's Festool. Shaper enables an unskilled carpenter to shape higher performance designs, possibly reducing material and waste, with the aid of cameras, a small number of registration markers, and a spindle with controlled eccentricity.

Enhanced Entire Workflows

AEC robotics are also being designed to enhance entire workflows. For instance, Autodesk is working with FactoryOS to capture construction knowledge and use robotics in the

construction line of its prefabricated modular homes to make workflows better, faster, and cheaper.[19]

Similarly, Autodesk's Robotics Lab is studying and calibrating intuitive user interfaces for automatically programming industrial robotic arms that could help move beyond the paradigm where every robot needs each motion to be preprogrammed.[20] This could usher in a "sense-plan-act" paradigm for closed-loop control models.[21]

Figure 1. Piaggio Fast Forward's gita robot is a first-of-its-kind cargo-carrying following robot that efficiently navigates pedestrian-dense environments helping people walk more, walk farther, and allow them to do more of their everyday living and working on foot. (Credit: Piaggio Fast Forward).

The sense-plan-act paradigm is already creating invaluable societal benefits in agriculture. Deepfield Robotics, a Bosch start-up, is deploying units able to navigate autonomously in the field, capture video, categorize, and root out weeds while avoiding crop damage.

In another application Robotiz3d[22] is a prospective autonomous road maintenance system designed to fix potholes in roads by detecting and fixing cracks.

The refit versus replace paradigm—which aims to extend the life of an asset—is the motivation behind Dynamic Infrastructure, developed with the Utah Department of Transportation to provide predictive maintenance for bridges using ML models with historic data and drone image captures.

Similarly, Arup has been working with CERN to research predictive maintenance with 360-degree photography mounted on permanent tracks and robots in tunnels using ML models to help predict and prevent degradation.[23]

Robots Solving Non-Trivial Problems

This review illustrates how the AEC industry can benefit from future robotics technologies. The potential of robotics is no longer limited to increases in productivity and no longer requires simplified repetitive single tasks. As these examples show, robots are now being designed to support contractors in meeting work skills shortages, improving safety, and

making viable the complex solutions necessary to address sustainable development challenges.

Notes

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