Smart Construction under the Background of Population Aging

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Abstract. The use of robots in the labor-intensive construction industry can save a lot of manpower and avoid personal injury to the greatest extent, while also greatly improving work efficiency. This paper proposes new solutions for the future construction industry under the background of an aging society through the application research of several typical construction robots.

Keywords: Aging, Construction Robotics, Solutions

1. Introduction
In 2016, the population of senior citizens aged 60 and above in the BRICS reached 400 million, accounting for about 42% of the world’s elderly population. It is expected that the population will increase to 630 million in 2030 and reach 940 million in 2050, accounting for 45% of the global population at the time. In the BRICS countries, the challenges faced by China in the ageing issue are even more severe. The problem of ageing population and aging population makes our task of dealing with population aging even more arduous. The aging of China’s population has become increasingly serious [1].

Statistics show that as of the end of 2016, the number of elderly people aged 60 and over in China exceeded 230 million, accounting for 16.7% of the total population; the elderly aged 65 and over exceeded 150 million, accounting for 10.8% of the total population. It is estimated that by 2050, the elderly population in China will reach 480 million, accounting for about two-fifths of the senior population in Asia at that time and one quarter of the global elderly population. This is more than the combined population of the United States, Britain, and Germany. The ageing issue will bring new challenges to China's socio-economic development and transformation [2].

In the United States, the construction industry accounts for about 10-15% of the GDP, and the annual workload is close to 400 billion U.S. dollars [3].

The construction industry is an important pillar industry of our national economy. In recent years, my country’s construction industry has continued to develop rapidly, the scale of the industry has continued to expand, and the construction capacity has continued to increase. In 2019, my country’s entire construction industry achieved an added value of 7,090.4 billion yuan, an increase of 5.6% over the previous year, accounting for 7.16% of GDP, Which strongly supported the sustained and healthy development of the national economy.
For a long time, my country's construction industry has mainly relied on the input of resource elements and large-scale investment to drive development. The construction industry has a relatively low level of industrialization and informatization, extensive production methods, low labor efficiency, large consumption of energy resources, and insufficient technological innovation capabilities. It is prominent that the construction industry is not sufficiently integrated with advanced manufacturing technology, information technology, and energy-saving technology, and the development and application of the construction industry Internet and construction robots are insufficient.

Increasing the R&D and application of construction robots, effectively replacing labor, and performing safe, efficient and accurate production and construction of construction parts and components has become a hot spot in the global construction industry. The application prospects of construction robots are broad and the market is huge. At present, my country has made significant progress in the research and development and application of intelligent construction equipment such as general construction machinery and bridge erecting machines and building machines. However, in terms of component production and on-site construction, the application of construction robots is still in its infancy and has not yet been realized. Large-scale application [4].

Due to the difficult working environment in the construction industry, many young people are reluctant to engage in this type of work, resulting in a shortage of workers in the construction industry. Frequent accidents, poor working conditions, shortage of skilled labor, and low production efficiency are common problems in my country's construction industry. An effective way to solve these problems is to realize the intelligentization of the construction industry.

2. Methodology
The development of construction robots originated in Japan. In 1982, a refractory spraying robot named SSR-1 by Shimizu Corporation of Japan was successfully used on construction sites. This is considered to be the world's first construction robot for construction [5]. The John Deeve 690C roadheader of the US military was used to repair the runway destroyed by the explosion; the trackbot and studbot of the Massachusetts Institute of Technology were used for the internal construction of the wall [6].

Japan's Shimizu multi-function walking vehicle (MTV-1) can smooth and polish the surface of concrete floors, and can automatically avoid walls and columns; exterior wall spraying robots can automatically spray the middle layer of the exterior wall and the protective layer, and the operating efficiency is 5 times the labor; the tunnel drilling machine of Kashima Construction Co., Ltd. of Japan can perform drilling, blowing, cleaning and spraying of concrete; the radioactive concrete cutting robot is used to dismantle the cement column of nuclear power plant [7].

The exterior wall automatic painting robot developed by Inha University in South Korea and Daewoo Institute of Architectural Technology can realize automatic painting [8].

The six giant funnel-shaped sunshine valleys in Shanghai World Expo Park are large cantilevered, irregular, and beautifully shaped steel structure buildings with a maximum diameter of 90 meters at the top and a maximum diameter of 20 meters at the bottom. The key nodes connecting the entire steel structure of Sunshine Valley are completed by robots, using fully digital and automated production processes.

The welding robot developed by the Equipment Technology Research Institute of Beijing Institute of Petrochemical Technology once completed the sub-structure welding work in the "Bird's Nest" venue of the Beijing 2008 Olympic Games. With the development of cities, high-rise buildings, steel structure buildings, social public buildings, especially large-scale national projects have higher and higher requirements for construction quality, efficiency and environment, and traditional manual construction can no longer meet the requirements [9].

Since 1996, Beihang Robotics Research Institute has developed various types of curtain wall cleaning robots for different application scenarios. In 2011, the "Indoor Panel Building Robot System" jointly developed by Hebei Construction Engineering Group and Hebei University of Technology
solved the interior decoration and decoration problems that have plagued the construction industry for many years [10].

2.1. SAM Robot

![Figure 1. SAM Robot in work](image)

The development of the New York start-up Construction Robotics has already replaced people on several construction sites in America.

Analysts still break javelin in disputes over whether technological progress will create additional vacancies or, on the contrary, will cause massive unemployment and social collapse. And if in most industries the situation is still uncertain, the trend in the construction business can be called frightening. So, for example, the robots-masons SAM (Semi-Automated Mason - semi-automatic mason) are able to lay up to 3000 bricks during the time, when the professional mason will lay 300-500 [11].

The robot SAM consists of a conveyor, an industrial manipulator and a pump for supplying mortar. SAM works as follows: the builder submits bricks to a small conveyor, where they are picked up by a robotic industrial manipulator, covers with cement mortar and masonry. The second worker removes excess solution from it. The quality of the resulting masonry is very good, the robot does not get tired and does not mess.

The SAM robot can handle all these problems through a set of algorithms, sensors that measure tilt angle, speed, direction, and lasers. The laser is mounted between the two extremes of the robot's work space, the leftmost and rightmost sides of the robot. As the work progresses, the laser moves up and down along the wall and can be used as the positioning point of the robot. Without the positioning of the laser, the robot did not know where to lay the bricks and could not measure the movement on the bracket. The SAM robot weighs 1500 kg and the machine is equipped with a Cummins engine that uses gas.

The SAM robot control system software uses innovative R&D results. The uniqueness of the program is bricklaying "drawings", which can digitally load wall and brick layouts and correlate with GPS/Gronas coordinates. Software can correct changes in real conditions in a building project. When the overall structure is corrected, the state of each brick of the corresponding wall can be determined. In this case, the construction plan accurately matches all actual real dimensions and boundaries.

Moreover, the pre-study of this project can be presented to customers through computer graphics tools in the form of computer programs. Customers can clearly find out how to build a brick wall, evaluate different color schemes or, for example, see how they view the company's logo. The control software can load digital images and other wall images. Even the software can calculate how many bricks are needed, how much time is needed to build the walls, and all the bricklaying information can be obtained in advance, which cannot be achieved by traditional manual methods.

In order to ensure that the SAM robot works requires three individuals: operator, brick and mortar assistant to the machine, and bricklayers that embed anchor bolts on the walls, remove excess mortar, and repair minor defects. According to company calculations, bricklaying production efficiency Raise 3-5 times, reduce labor costs by 50%, build bricks that take 12-14 seconds depending on size, SAM100's market price is 650,000 USD, and investment recovery period is 1-2 years.
The average age of a third of all British builders exceeds 50 years - this means that more than 620 thousand people will retire in the next 10 years. At the same time, there is an acute shortage of housing in the country. So for the massive use of robots on British construction sites, as they say, the time has come - experts expect that the process of their implementation will begin in the next couple of years.

The robot SAM can easily cope with window apertures and plumb bows, but cannot build corners on its own. On the assurances of the developers, the operation of 6 systems costs construction companies $ 20,000 per month. The cost of a robot by Russian standards is considerable - about $ 0.5 million. On construction sites in the United States and the United Kingdom, robots will pay off, the developers are sure. And in Russia, probably, the services of guest workers will still be cheaper.

SAM is not the only automated system designed for the erection of brickwork.

2.2. Hadrian X

![Figure 2. Hadrian X in work](image)

Hadrian X is controlled by an electronic system, which loads the architectural plan in 3D digital format. The main part of the equipment is to install a 28-meter telescopic boom on a mobile chassis and use it to complete the task. The telescopic boom can correct the state up to 1000 times per second to compensate for the influence of wind gusts and other natural factors.

Productivity of the system is up to 15 thousand bricks per day. For this, a vision system based on lidars is used. The robot has been building houses in Australia since 2016 [12].

2.3. In-Situ Fabricator

![Figure 3. Work place of In-Situ Fabricator](image)

In-Situ Fabricator was founded by a team of architects and robotics technicians at the ETH Zurich. The robot is relatively light, mobile, and the most important is having "smart". It is equipped with two computers, one of which is responsible for robot movements and the other is responsible for positioning. The robot has a laser rangefinder. When the robot moves, the rangefinder scans the space around the robot and creates a 3-dimensional graphic of the surrounding space. Even load the building digital model in the airborne control system. Using these data robots to continuously determine their own status and complete construction business in a changing environment, creating possibilities for autonomous work and achieving accuracy of micron level. There is also an advantage that IF has the ability to move automatically at the construction site without the need for manpower. The robots are
equipped with sensors and cameras. They keep the robot from hitting obstacles and people while exercising [13].

2.4. Flying Construction Robot

![Figure 4. Flying construction robot in work](image)

The Institute for Dynamic Systems and Control in Zurich (Switzerland) has developed the concept of a “flying robot” that can build buildings autonomously without the need for human intervention in the construction process. The system can control different aircraft, but because of its mobility, simplicity of the mechanical device, reliability and strength, and ability to hover in the air, the quadcopter was chosen.

The quadcopter is equipped with an onboard electronic control system, an angular speed gyro sensor and an accelerometer. The bricks are held by special fixtures with servoed three pins.

The success of construction depends on the accuracy and reliability of brick placement.

Research shows that the most accurate and reliable method of laying bricks - through air transfer and laying without using gravity.

The quadcopter brings the bricks to the building and calculates the trajectory of the bricks laid on the wall at a given speed.

Studies have shown that the lower the speed at which bricks fly toward masonry (and, correspondingly, the smaller the impact on paving), the greater the accuracy of the influence of turbulent trajectories and gravity in the air. Therefore, it is preferable to lay bricks at a sufficiently high speed without the need for "carefulness".

The ability of a group of robotic planes to construct buildings is reflected in practice: a typical building has a ratio of 1:100, a building height of 600 meters, 180 floors, a building area of 180 square meters, and a total area of 1.3 million square meters., for 30,000 people to live - a real building project "Future Autonomous House" 6-meter-high building structure consists of 1,500 bricks, four-axis aircraft took only four days.

The control program controls the flight trajectory, excluding the collision of the machine: Before the quadcopter completes the maneuvering operation, the system reserves free space for this purpose so that other machines do not enter its path, and the system does not allow other machines to enter the reserved space until the maneuver is over. The system can prevent the collision of a drone with a vertical structure - that is, all the space occupied by the tower is considered "reserved", and the drone cannot be laid through its own flight path.

The wireless system uses speed and maneuver control to grab and place bricks and all powerflights, and can distinguish the number of flying robots participating in the construction at each moment and the bricklaying speed (brick/hour) [14].

2.5. 3D Printer
3D printing technologies conquer the world and this is a real scientific and technological revolution that is taking place before our eyes. Looking at the speed of translating into everyday life ideas that have been fantastically fantastic recently, such as the production of a large-scale printing of artificial hands by human hands, not only futurologists, but also experts confidently speak about the future significant changes in the life of human society. And if in some sectors of the economy the practical applicability of 3D printing is no longer in doubt, this is medicine, engineering, radio engineering and electronics, then in such a weighty industry as construction, bulk printing robots look like expensive toys. As you know, the main difference between a 3D printer and any other industrial robot in the way of creating products. In particular, the building 3D printer has a nozzle or extruder and squeezes out of it a quick-hardening working mixture. The surface on which a volumetric product is created is called the working area and has dimensions determined by the stroke size of the nozzle. And formwork is not required. That is, the volumetric printing machine is declared as a self-sufficient mechanism capable, when connecting electricity, literally on a bare ground to create a finished building.

There are three known ways to create a volumetric construction: Layered extrusion of a viscous working mixture.

In this case, a creamy mixture of concrete with additives is squeezed out of the working "nozzle", like a toothpaste from a tube.

The first to substantiate the concept of using a robot in construction, in the form of a manipulator crane, laying a viscous concrete mixture for a given program, industrial designer Sergei Dudin, together with specialists from the Mendeleev MHTI in 1995. The first public presentation on a similar technology in construction, organized by Professor Baruch Koshnowitz from the University of Southern California in August 2012. His group also put forward the concept of a gigantic, assembled on site construction of a printer by the type of a bridge crane. A group of scientists led by Dr. Sungwa Lima of the British University of Loughborough University published the world's first hollow panel with double rounded contours [15].

3. Results

In summary, with the continuous development and progress of artificial intelligence technology and digital construction technology, construction robots have irreplaceable advantages and application prospects in the construction field. Construction robots can better solve the problems caused by an aging society, and at the same time, Individualized and irregular building forms provide the best solution.

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