Current Status and Key Issues in the Future of Automation and Robotics in Construction in Israel

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ABSTRACT

The format of this brief status report is that of an extended abstract. Its purpose is to highlight more than a decade of development, and show how an apparently futuristic idea gradually transforms to an inevitable practical solution. It focuses mainly on the steady activity of Technion - Israel Institute of Technology - in the promotion of Automation and Robotics in Construction.

1. THE ACUTE PROBLEM OF LABOR SHORTAGE IN CONSTRUCTION

Similarly to other Hi-Tech societies, Israel also faces a severe shortage in construction laborers. Despite various incentive programs, run by the National Association of Contractors and Builders, by the Labor Unions and by the Ministry of Construction and Housing, the young generation does not join the industry in sufficient numbers to replace retirees. The "temporary" solution of allowing the import of foreign labor from different parts of the world for limited periods, has become an annoying permanent phenomenon with numerous negative social implications. Automation and Robotics in Construction has higher prospects, under these circumstances, to receive public recognition as a promising long term solution.

2. INITIATIVES OF INDUSTRIALIZATION AND PREFABRICATION

In response to the labor shortage, many construction companies, developers and designers have been reviving existing methods of prefabricated and industrialized construction techniques, as well as adopting, adapting and developing new ones. Their main concern in this trend is to minimize labor input on-site and replace conventional, difficult and dirty works by easier and more professional assembly activities. One example is the use of steel skeleton and prefabricated curtain-walls for the construction of mid-rise residential buildings.

3. GENERATING AND TESTING IDEAS OF AUTOMATION IN CONSTRUCTION

The source and center for initiatives in the field of Automation in Construction since the early eighties has been the Technion - Israel Institute of Technology. A team of academicians firmly believed that the construction industry has no other viable option for the long run. A comprehensive conceptual framework of Construction Automation was developed by Prof. Warszawski, and ever since a steady stream of larger and smaller projects has been followed. They are grouped in the next sections.

4. DEVELOPMENT OF A MULTIPURPOSE INTERIOR FINISHING ROBOT

The development of a building robot for interior activities was tested first on a small scale by an educational robot fitted with special end effectors to demonstrate wall building, painting, and the sealing of joints. At the same time, additional experiments involved graphic simulation on the computer models of typical buildings. Various configurations of robots were examined with respect to their time-performance and ability to reach all required places without collisions.

Upon completion of the basic feasibility study, the time had arrived for the first full-scale prototype named "TAMIR" - standing for: Technion Autonomous Multipurpose Interior Robot. "TAMIR" consists essentially of a robotic arm mounted on a computer-controlled carriage. At each workstation the robot deploys its four stabilizing legs and performs a brief procedure of levelling and calibration prior to getting down to the task. So far, "TAMIR" has learned three kinds of building tasks, each of which stands for an entire family of operations: Tile-setting, paint spraying, and wall building.

Tile setting on walls represents a number of very accurate building tasks: The robot is equipped with a vacuum gripper by which it lifts the tiles from a cartridge and brings them to their precise location on the wall. Glue is applied in advance either on the wall or on each tile separately. The robot gently presses the tile against the wall until the glue reaches its proper thickness. Robotic tiling is much more accurate than manual work and three times as fast. This process will, in future, be done wholly automatically.

The next tasks - of the same robot - represent building activities in which the end-effector does not touch the treated surface. Painting and plastering are done with a spray gun whose trajectory, speed, and material flow are all computer-controlled. In spraying, the robot releases human workers from hard, monotonous, and unhealthy work. The quality of the work is uniform, and its speed can be at least 5 times as fast as human labor.

In wall building, the robot demonstrates its ability to cope with even more complex tasks: This application utilizes extra large, yet lightweight, building blocks whose edge-profilation facilitates their accurate positioning. At each cycle the robot measures and corrects its grip on the block with the aid of special sensors. Upon arrival at the wall the block is fitted into its exact place by controllable forces. Here, too, the robotic work is five times as fast as manual labor.

The last stage of the project to date was an economic comparison between robotic and manual work. The robot's fixed and variable costs were taken into account, along with a dedicated operator and complementary manual works. In spite of the considerable initial investment the economic analysis reveals that the application of robots in building is cost effective. This conclusion will gain strength in the future due to the trend of rising labor costs - which is particularly noticeable in construction, and - at the same time - the reduction in the cost of robots owing to their mass production.

5. AUTOMATION OF EXISTING CRANES FROM CONCEPT TO PROTOTYPE

This project, led by the author, involves the conversion of an existing full-scale 5-ton payload crane into a semi-automatic "Handling Robot". By its size, degrees of freedom, and mode of operation this crane resembles typical construction cranes, which can be enhanced in the same manner. The new control system allows operation of the crane in either a manual or a semi-automatic mode, and it can be taught to memorize up to 50 different benchmarks, i.e. particular points at the construction site, as well as safe routes among them.

The major components of the system include: a programmable controller, three speed regulators, three encoders, several limit switches, a wireless remote control set, and a user-friendly M.M.I. (Man-Machine-Interface). Most of the components can be installed *externally* in the vicinity of the crane's joints and inside the cabin, with minimal intervention in the original wiring.

Following the physical retrofitting of the crane, a series of tests examined performance, accuracy, repeatability, and safety aspects. They demonstrated a 15-50% shortening of typical work cycles, high accuracy and repeatability, and a generally safer operation due to pre-tested paths and smoother movements with less sway and swing of the load. The project creates much interest for commercial development.

6. CAD-CAM APPLICATIONS IN CONSTRUCTION

A series of projects led by Dr. R. Navon involves the integration of computer-aided design with computer-aided construction. The general concept was labeled as COCSY (= CAM Oriented CAD System) aimed at automatic extraction of construction-related data from the design database and using them directly for the production of components and assembly on site. One specific application involves a fully automated rebar manufacturing machine with the aid of a graphic simulation system, which may lead to substantial cost reduction together with increased quality. A second specific application involves the automatic transfer of tile-setting patterns on walls from the drawing files directly to a robotic work plan.

7. MAN-MACHINE INTEGRATION IN CONSTRUCTION WORKS

This group includes a whole array of mainly conceptual developments and initial testing with the aid of graphic simulation. Several members of the "SHAMIR" (=Surface Horizontal Autonomous Multipurpose Interior Robot) family include floor tiling robots, carpet laying robots, outdoor "tiling" robots as well as material handling and serving robots. These projects are not yet matured but carry great promise if initially introduced as "man-machine integrated" rather than fully autonomous. A similar man-machine approach is also applied to other, less-structured and less repetitious, building tasks.

8. OTHER HIGH-TECH AND COMPUTER INTEGRATION IN CONSTRUCTION

Numerous other research and development activities fall within the broader framework of Automation in Construction. These include, inter-alia, advanced fully- or semi-automated robotic mapping of building interiors with the aid of laser range finders, ultrasonic sensors, infrared sensors and computer vision. The latter is also used for real-time quality control of robotic construction.

Other advanced computer-related projects include the development of a comprehensive "Building Project Model" for automated building systems, as well as Automated Real-Time Control of manpower productivity and other managerial data on-site.

9. FUTURE TRENDS IN CONSTRUCTION AUTOMATION

The experience-based assessment of the author is that Automation and Robotics in Construction should proceed in parallel on two paths: On the one hand we must not lose the far-seeing vision of an almost fully-automated, fully-autonomous construction process, and in the academia we must continue developing and testing the feasibility of such ideas. On the other hand, however, we must be practical and realize that the profit-oriented and very much fragmented construction industry will naturally prefer short term immediate solutions to its labor shortage problems. The players in this market, as well as many of the politicians involved with it, are not concerned so seriously with the social and moral implications of the import of cheap labor, to build the economies of the developed countries.

Consequently, the automation of the construction industry is still expected to be a long process. The most promising applications are bound to be the Man-Machine integrated innovations, that can be economical despite the abundance of cheap labor. These applications will be viewed as a natural extension of present technologies, and will pave the way for fully automated systems in the long run.

Ultimately, the potential of automation and robotics in construction is enormous: On the future construction site robots will work day and night, non-stop, without getting tired, while a handful of operators will watch them from an air-conditioned control room. Other industries have already implemented this new work style, and we, the Construction Industry, should also harness the advanced technologies of the twenty-first century.