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Research Paper

# Contribution Of Advanced Technology: Automated Data Collection In Resource Management

Engineering

**KEYWORDS:**
automation, construction, technologies, data collection

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## ABSTRACT

The construction industries are labour intensive, project based and slow to adopt emerging technologies. Construction industries is not only one of the most dangerous worldwide, but also prone to low productivity and cost over runs due to shortages of skilled labour , unexpected site conditions ,design changes, communication problems, and unsuitability of construction means and techniques. Construction automation is emerged to overcome these problems. Construction automation has the potential to capitalize on increasing quality expectations from customers, tighter safety regulations, and greater attention to computerized project control. Now a day, many construction operations have incorporated automated equipment, methods into their regular practices. In this paper, provides an overview of construction automation and focus on the contribution in construction from robotics.

## INTRODUCTION

construction automation is the work using construction techniques including equipment to operate and control construction production in order to reduce labour, reduce duration, increase productivity, improve the working environment of labour and decrease the injury of labour during construction process. In 2000, robotics applications in construction industry completed 20 years of research, exploration as documented in the first book on robotics in civil engineering. The applications made important contributions to replicating single tasks, which would be completed speedy and safely when no labours were operating equipment. However, the cost of robots is very high .Construction automation uses principles of industrial automation to streamline repetitive tasks, such as just in time delivery systems or computerized information management systems. Automation has been associated with repetitive processes and robots are prepared for doing specific task in systematic manner.

## HISTORY OF AUTOMATION

A wide variety of industrial robots has been introduced into various industries since late 1970s.

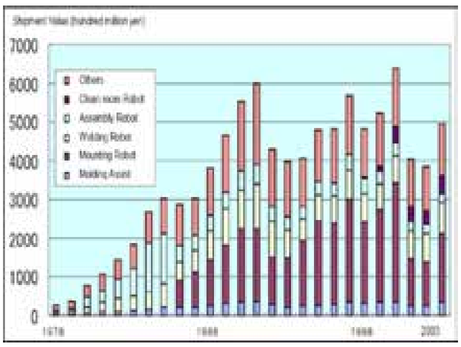


Figure 1 Trend of industrial robots (Amount shipped by category) Robot
Source: Robot Policy Study Committee, METI

### Construction Automation in1980s

The bubble economy, which lasted from the middle of the 1980s to the beginning of the 1990s, brought an active demand to the construction industry, which caused the industry a serious labor shortage and steep rise in wages of skilled workers. From the mid-1980s to the early 1990s, building contractors, especially major general contractors, made aggressive investments to develop building automation, and to introduce a wide variety of robots and automatic systems to their construction fields. According to a study conducted by the Architectural Institute of Japan, about 150 robots were developed during the period. At the same time, steel fabricators started introducing welding robots in the mid-1980s. According to Professor Nakagome of Shinshu University, welding robots were first introduced to mid-sized steel frame fabricators which were exposed to severe cost competition during the period.

### Construction Automation in1990s

Combined with the development of the robots, automatic systems for entire building construction started to be developed around 1990.The systems combine automation technology, such as building robots and automatic transferring system, industrialization technology, such as prefabrication and unitization, and computer technology for controlling the systems. These systems are intended to make conveying and fabricating work more efficient those highly automated systems reduced heavy manual labor and realized comfortable all weather type work environment. They eliminated high-place works and significantly reduced industrial accidents due to the accidental falling of workers, materials and equipment by the use of peripheral enclosures. The all-weather feature of the systems allows lifting work in windy days, which can otherwise be very dangerous. Those systems, along with the development of prefabrication and unitization, have improved the quality of construction significantly. The productivity has also been improved significantly, as a result of the new automated methods for transferring, assembling and joining, along with the all-weather features of the systems.

### Construction Automation in 2000s

Even after the turn of the century, construction companies have been exposed to sever competition due to prolonged slump of the economy and the weakened demand for new buildings. Cost has become a key factor in receiving orders, and robots and automated systems are subject to severe scrutiny for their cost effectiveness. As described previously, there were around 150 types of robots developed during the period of bubble economy, however, most of them, with a few exceptions, could never find real applications in the field and disappeared. The main reasons are:

- Most of the building contractors cut their R&D investments on building automation because of the slumping economy.
- Most of the robots developed were not versatile enough to meet the complicated requirements at construction sites.

## REVIEW ON VARIOUS TECHNOLOGIES USED FOR AUTOMATED DATA COLLECTION

This section gives a brief review on some of the stand-alone technologies that are being investigated for potential applications in construction.

**Barcode**: It is an established and affordable technology as shown in Fig. 1, but it has presented problems in the construc-

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tion due to the short read range and pure durability of barcodes as they require a line of sight and become unreadable when scratched or dirty.

**Figure 2 Barcode technology**
Source: http://www.google.co.in/imgres/barcode

RFID (Radio Frequency Identification): Passive RFID tags are different from battery powered active RFID tags and are much less expensive. Active tags have a read range of10mm to approximately 5m. RFID tags do not require line of sight to be read and can be read through most materials. Cost is a currently significant factor limiting the wide spread use of RFID tags in the construction industry. Limitation of active RFID technology is that it requires battery management since the life time of an internal battery is 5-10 years.

**Figure 3 RFID tag and reader**
Source: http://www.google.co.in/imgres/RFIDtag

GPS (Global Positioning System): With over 20 years of development, the current stand-alone GPS can lock positions with accuracy around 10m. The positioning accuracy of 1 to2m can be achieved with the technology of DGPS (Differencing GPS) and RTK GPS (Real Time Kinematic GPS) can further enhance the positioning accuracy to even millimeters. The application of GPS in high areas is likely to be hindered by blockage of satellite signals and due to multipath effects. GPS does not function well indoors as the building structure itself hampers reception of satellite signals.

**Figure 4 GPS System**
Source: Review on automated data collection in construction by Liju Joshua and Dr. koshy Varghese

UWB (Ultra Wide Band): This system uses carrier less, short duration (picoseconds to nanosecond) pulses with a very low duty cycle. In 2002, FCC has approved the commercial use of the UWB systems. It operates in 3.1-10.6 GHZ range. This technology is used for radar applications, communication applications and also for active radio frequency tracking and positioning applications (Fig. 4).

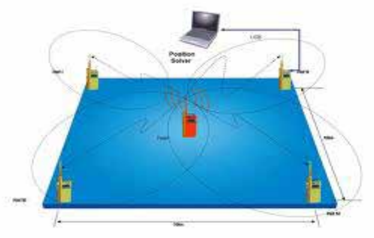

**Figure 5 UWB system for positioning application**
Source: http://www.google.co.in/imgres/ UWB system

LIDAR (Light Detection and Ranging): This is a 3D laser scanning system that scans real objects and the spatial information data are stored as or transformed to be stored as a group of x, y and z coordinates. LIDAR equipment is shown in Fig. 5. The data of spatial information can be exported to computer aided design applications for additional modeling. 3D scanners are able to collect millions of range points in a few minutes. But rapid modeling of a construction work zone using 3D imaging is a challenging task because job sites usually contain a large number of complex shaped construction shaped construction resources such as materials, temporary facilities and equipment.

**Figure 6 LIDAR Equipment**
Source: http://www.google.co.in/imgres/LIDAR

Flash LADAR (Light Detection and Ranging): This 3D ranging camera (Fig. 6) operates at fast-time scales with large field of view and could be deployed in construction sites. But processing, analysis and interpretation of visual signals in real time is a difficult task.

**Figure 7 Flash LADAR Equipment**
Source: http://www.google.co.in/imgres

Calibrated Camera network: It is a collection of three or more vision sensors. They are called as smart cameras (Fig. 7) as they combine image sensor, on-board computing and capability to network with other nodes wirelessly. Stereo vision cameras are composed of two or more sensors and can provide 3D spatial data with its own RGB color value.

**Figure 8 Smart camera**
Source: Review on automated data collection in construction by

Wireless Sensor Network (ZIGBEE): It is a low-cost, low-power, wireless networking standard capable of short distance wireless control and monitoring applications. This network normally employs MEMS (micro electromechanical systems) sensors that are cheap and small in size. Fig. 8 shows an example of zigbee network with different kinds of sensors connected in the form of a mesh.

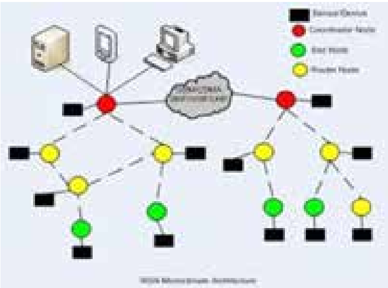

**Figure 9 Zigbee sensor network**
Source: http://www.google.co.in/imgres

**REVIEW ON THE RESEARCH WORKS CARRIED OUT FOR AUTOMATED DATA COLLECTION IN CONSTRUCTION**

This section gives a brief review of some of the recent research works carried out in the past couple of years and are grouped under fourteen categories.

**Material Management**

A joint delivery system is an excellent option when materials are to be delivered to several construction sites from a common supplier. RFID technology can be used for tracing and delivering the items minimizing transportation and handling difficulties. Considerable improvement in truck loading rate and reduced carbon dioxide emissions were reported from the experiments carried out.

A GPS unit and a handheld computer were used for locating pipe spools on lay down yards. Trimble's GPS pathfinder power was the GPS used and the hand held computer collected the positions determined by the GPS receiver. The field implementation showed significant savings in labor time and costs. The direct labor savings on a single project can easily offset the technology costs.

WSN can be implemented using Zigbee technology and Automatic material tracking is a very important application. Zigbee enabled sensors are attached to the objects and the distance of an object from the Zigbee router is based on time of-flight principle. Measurement of distance by RF signals and also by a combination of RF and ultrasound technologies were experimented and the latter one gave better accuracy.

RFID and GPS in combination present an opportunity to track large precast components with minimum worker input. The RFID tags containing unique ID numbers are placed on precast pipes and the RFID reader is mounted on the mobile gantry crane. At the times of pick up and release of the load the location of the crane is read from a GPS receiver which is also mounted on the crane. The ID and location information is then sent to a database for retrieval for shipping or for inspection.

The materials are tagged with RFID tags and can be tracked in two dimensions on construction sites when combined with GPS technology. Field experiments proved that RFID technology in combination with GPS enables tracking precisely the movement and location of materials at less cost than pure GPS or other existing approaches.

Material tracking using RFID alone has got many limitations and this study used WSN technology to overcome them. The material tracker has the RFID reader and the Zigbee sink node attached to it. The data collected from the tag through the RFID reader and the location status through sensor nodes are transferred to the server wirelessly. The Communication interference between Zigbee nodes posed a challenge for practical implementation.

**Progress Measurement**

Progress monitoring is possible in prefabricated construction using RFID technology. The components are identified in real time using tags and when integrated with MS Project the schedule gets updated automatically. The 3D model of the building also gets updated in the Auto CAD model. Inventory updating is another application that helps in field material management. Calibrated camera network offers solution for real –time monitoring. Calibrated network is a collection of three or more vision sensors whose positions and orientations in 3D space are known. They are smart cameras as they combine image sensor, onboard computing and capability to network with other nodes.

The major drawback with laser scanning is that it takes considerable time to process the data and the equipment costs are high. A 3D object recognition based on stereo vision system has the potential use in progress monitoring. Stereo vision system is composed of two or more sensors and can provide 3D spatial data and images from the same perspective. The final step is matching and comparing with obtained data from a planned data such as a 3D CAD model converted into STL file.

**Safety Control**

Alerting worker to the dangers of hazard based on the working area information of equipment is used for controlling collision accidents. RFID technology can be used for data collection for monitoring the working area. The experimental arrangement consists of tag, reader, data communication system, warning system and administrative server. The reader has WLAN function for transmitting collected tag data to the server.

Ultra wide band system has been used to develop a virtual fencing system for real-time safety management in construction. It is a proactive system as it constantly checks whether workers are accessing hazardous areas, using algorithm based on predictive approach. The system will predict in advance whether any worker is approaching a forbidden area.

Modeling dynamic objects like moving humans, equipment and materials in real time will enhance site awareness, a very important prerequisite for safety and this is possible using FLASH LADAR technology. This research used a prototype Swiss Ranger model for this purpose and it uses time-of-flight principle to capture 3D surface measurements. Experimental results showed that the accuracy levels are compatible with the requirements of active safety features for construction.

Image cameras were used to monitor the posture and movements of workers for ensuring their safety in an active work zone. A star skeleton structure was generated from the image and the system calculates the angles between different body parts to analyze the posture of a construction worker.

**Quality Control**

A PDA and wireless web-integrated system can be used for quality inspection. Data base is created with categories of facility, trade, space, contractor etc. and it is a relational database. The checklist is wirelessly transmitted to PDA through a central server system. Defect information is wirelessly sent to the central server and work orders are issued to the trade contractor through electronic mail.

**Location Tracking**

WLAN can be used for indoor tracking and GPS is an effective tracking tool in outdoor environment as there is a clear line of sight to the sky. But the transition between two technologies seamlessly for indoor and outdoor application is a big challenge. Head orientation data can be tracked using magnetic head trackers and together with position tracking gives the complete context awareness.

**Equipment Operation**

FLASH LADAR allows for real-time acquisition of 3Dinformation and can operate day and night. It is used for real time object recognition and modeling for heavy equipment operation. Objects are modeled by different combinations of data-processing techniques such as filtering, feature extraction and clustering. This spatial model assists in the movement and operation of heavy equipment, thereby enhancing efficiency and productivity of automated equipment

**Maintenance Management**
Open-building philosophy advocates for the usage of reusable and changeable building elements for enhancing the flexibility of buildings and decreasing the resource consuming situations in the maintenance phase. RFID tags containing raw design data can be embedded in to the building elements that they automatically provide the essential data for remodeling. The CAD and image files are stored in the database associated with components by key numbers.

**Labor monitoring**
In this research workers' locations are measured automatically at regular time intervals. From this data the labor input information can be deduced using computerized algorithms. GPS technology is used to measure worker's locations on site. A GPS receiver was mounted on a worker's construction helmet and tested during construction of an eight story building. This can be integrated with a building project model enables interpreting the quantity of labor hours Consumed in a task.

## THE AUTOMATED WORKPLACE

**Effect on Skilled Labour**
Robotic machines can perform certain unpleasant and dangerous jobs such as welding or painting. They can handle loads of up to a ton or more and work efficiently in temperatures ranging from near freezing to uncomfortably hot. In many cases automation has eliminated physical and mental drudgery from human labour and has allowed the worker to change from a machine operator to a machine supervisor.

Automation also boosts productivity (as measured in output per man-hour), even as it reduces the number of workers required for certain tasks. In the 1950s and '60s, for example, productivity increased while employment decreased in the chemical, steel, meatpacking, and other industries in developed countries. Except in the rust belt regions (older industrial areas in Britain and the United States), no mass unemployment has ever materialized. Instead, as certain jobs and skills became obsolete, automation and other new technologies created new jobs that call for different skills.

Automation has brought about changes in the worker's relationship to the job. Here the differences between labour practices in different countries prove instructive.

## THE FUTURE OF ROBOTICS AND AUTOMATION IN CONSTRUCTION

The automation in construction has moved through several historical periods, according the ISARC trends (Ueno, 1998): a) cradle (1984-85), b) growing (1986-89), and c) developing (1990-98). However, even at the time of preparing this document one can assert that the consolidated has not been achieved yet. This may happen in the near future, but it is difficult to imagine that the houses will be built in the future like today's cars. However, as illustrated in the examples above the automation in construction is increasing and many of the developed prototypes will see their way to real application. Some factors are very important and will affect the way to real implementation in the near future. These factors are summarized as follow:

- Change of attitude in the construction companies, the machinery industry, the research centres and the government R&D officials, in order to develop new high tech commercial products and pass the phase of prototypes.
- Implementation of new IT and telecommunications technologies is already changing the work process in all the social segments, including the construction people. Today's form of work is unimaginable only a few years ago.
- Globalization of the market and consequently adaptation of the commercial structure in today's construction sector introduces a very high level of competitiveness, which urges companies to adopt more automated and efficient means. To achieve the consolidation period in the construction automation big efforts need to be made in different fronts:

**Integration**
This is one of the key issues which are necessary to be consolidated during the next years, being the main lemma "from architect's desk to site robots". For this purpose three main actions should be taken:
1.1 Feedback design of houses, taking into account the prefabrication, erection, assembly, transportation and other stages of the construction process.

1.2 Diversity of the design using the highest number of the similar standard prefabricated elements (i.e. building different houses with the same parts).

1.3 Software standardization which permit the easy and fast data exchange between architects, civil engineers, electrical engineers and computer science experts.

2. Pre-fabrication
Expand this technology to cover other materials other than the concrete (including composites), which shall immediately boost the productivity. Three main actions are:

2.1 Mass production using pre-fabrication in order to select the parts from a catalogue. This means that CIM concept must be introduced, including JIT production.
2.2 Standardization of the maximum number of parts through the use of grid dimensions, common joints, connections, etc.
2.3 New materials for pre-fabricated parts which make them lighter, maintaining the same mechanical features.

**3. Robots and automated machines**
The robots and highly automated machines are the key issue. Using them ensures a high level of productivity. Some of the main actions are:

- "Easy" to use robots. Develop robust robots which are easy to control and program through friendly human machine interfaces.
- Cheap robots. Develop cheap robots which cover single type of application, being not general. This will permit to increase the sales of units.
- Increasing the level of automation of existing machinery. Modify the conventional construction machines (cranes, compactors, etc.) in order to convert them into robotic system.

**4. Investment in R&D**
More research and developed investment in RAC both in basic and applied research through national and international targeted programs, such as the EU research frameworks. One of the main objectives has to be targeted also at changing the culture of the operators directly involved in the construction process, through education and training. Otherwise the operators would resist the introduction of innovation.

## CONCLUSIONS

- Robots are increasingly involved in construction operations to maintain highly accurate actions and to reduce hazardous risks achieving improved control and safety.
- Automated construction can be further developed to include: design, engineering, maintenance of existing and planned structures.
- Many research works suggest highly autonomous robotic system for the construction performance. The "Sense-and-Act" may indeed become a reality in the development of more advanced robotic systems for construction applications.
- Real-time planning is commonly employed in tasks that require the robot to contend with uncertainties and undefined environments.
- Efforts should be paid to convince professionals in building management to look into the possibility of integrating robotics and building. Automation together to improve the

quality of services for modern intelligent buildings.

- All new ideas for Automation or robotizing on the building site have to be generated by a Combination of new designs, new forms and new materials that meet the requirements for building in a metropolis.
- With intelligence activities such as generalization, analysis and decision-making for multi-objectives, there can be a better understanding of the construction engineering problem.

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