Emerging Technologies for Construction Data Collection

Han, Seungwoo*

Abstract

Estimation based on current data of construction performances have become one of the critical subjects which many researchers have been interested in for the past decades. In order to accomplish accurate measurement and estimation of construction performances, the method of data collection stands the highest priority. However, there are many difficulties in data collection from construction jobsite due to the characteristics of the construction industry. With developments of new technologies in other industries, several technologies has recently initiated to be applied to construction field. Electronic tags based on the identification technology, automatic volume measurement based on laser scanning technology, and Global Positioning System (GPS) have been represented the technologies which show the high opportunity for being used in construction. This study reviews specific aspects of these technologies focused on the utilization in construction jobsite. Also, the challenges which these technologies need to overcome are discussed.

Keyword: Construction data collection, Emerging technology Identification, Volume measurement, GPS

1. Introduction

1.1 Problem statements

One of main goals which all industries have been seeking for long times is to get the enhanced performance. This performance can be involved in all aspects of the construction process as both concept of productivity and quality in the construction industry. In order to coincide with the goal, many researchers have concentrated on job studies. Job studies are mostly focused on construction equipment fleet management which has become one of critical concerns for field engineers or managers working on jobsites to find an efficient way to increase productivity. However, field engineers or managers have been struggling for lack of data related to the positioning of equipment operating in the field due to the limitation of application of new technologies for identification of positioning and automatic volume measurement of material moved. These problems prevent researchers and engineers from evaluating current operation based on productivity and establishing efficient construction equipment fleet management.

1.2 Research objectives

Regarding identification and volume measurement, there are currently three new technologies with high opportunities to be applied in the construction industry; (1) the technology in identifying position (2) the technology in volume measurement, (3) Global Positioning System (GPS). These three technologies are discussed in this study.

The overall objective of this research is to analyze and evaluate the new technologies focusing on the identification technology and the volume measurement technology. The overall objective is met by the following specific objectives:

- Review the current trends of the identification technology and the volume measurement technology.
- Assess the state of the practice and procedures of technologies being capable of application to the

* Member, Ph. D. Assistant Professor in School of Architecture, Inha University
shan@inha.ac.kr

construction industry.

2. Identification Technology

Most positioning technologies generate sensor events in response to changes of location of target objects. Object identification technologies have been utilized in various applications such as asset tracking, and automated inventory. Electronic tags are the state of art of object identification devices developed by the automatic identification industry. Electronic tags are defined by Roy Want and Daniel M. Russell as machine readable device or label that identifies the host to which it's attached enabling the host objective to be more easily and accurately identified (Want et al. 2000).

Based on the viewpoint in construction, multiple object identification can be pointed out as another limitation for technology itself to be utilized in construction. The identification technology have been assessed in two cases; single object identification and multiple objects identification. When this technology was introduced, this was only focusing on identification for single number of object. However, in case of that many objects need to be identified at the same time, reliable identification of multiple objects is challenging. A few of technologies have been studied to solve this problem, but they proved not reliable to provide accurate information not interrupting with the rest of objects.

Radio Frequency Identification (RFID) is the most common and a key technology overcoming the problems of controlling in a distance and unreliability of multiple objects identification which are serious limitations of traditional barcodes which were dominating an automatic identification device market before. Thus, it conclude that RFID tags can be applied to the construction industry with high opportunities. (Want et al. 2000)

Trovan RFID tag by Trovan made from a coil, a silicon chip, and an encapsulating medium for protection, TIRIS Tag-it system by Texas Instruments in the form of planar labels with an aluminum spiral coil on acetate and flip-chip at its center, BiStatix Capacitive Coupled Tag by Indala, a subsidiary of Motorola consisting of an RFID chip and an antenna which is made from two plate electrodes, and I-Code by Philips Semiconductors are well-known RFID products in current RFID device market. More detailed specification and information about these products are well shown in papers by Want et al. (2000), Vogt (2002), and on their own websites. Figures 1, 2, and 3 shows the various types of RFID which is capable of being used in construction in current market.

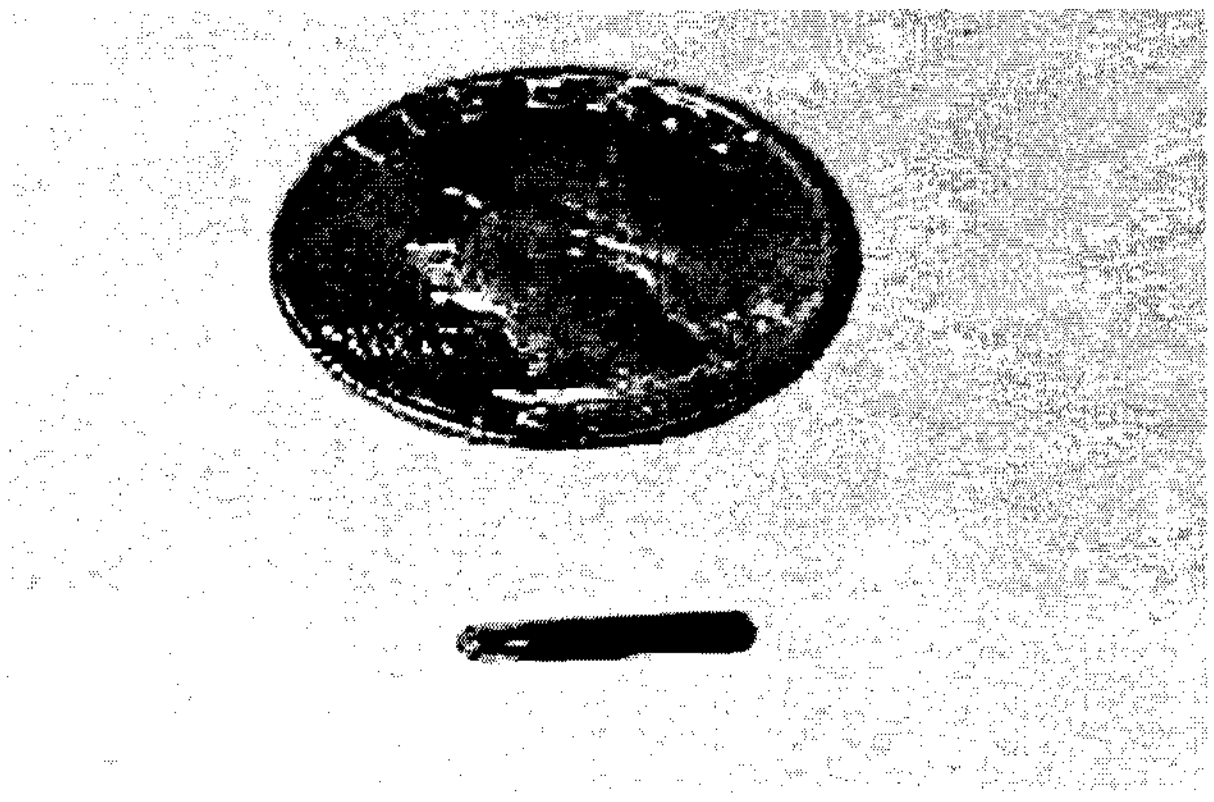


Figure 1. Trovan RFID tag by Trovan (Source; http://dsonline.computer.org/archives/ds200/ds2wan.htm)

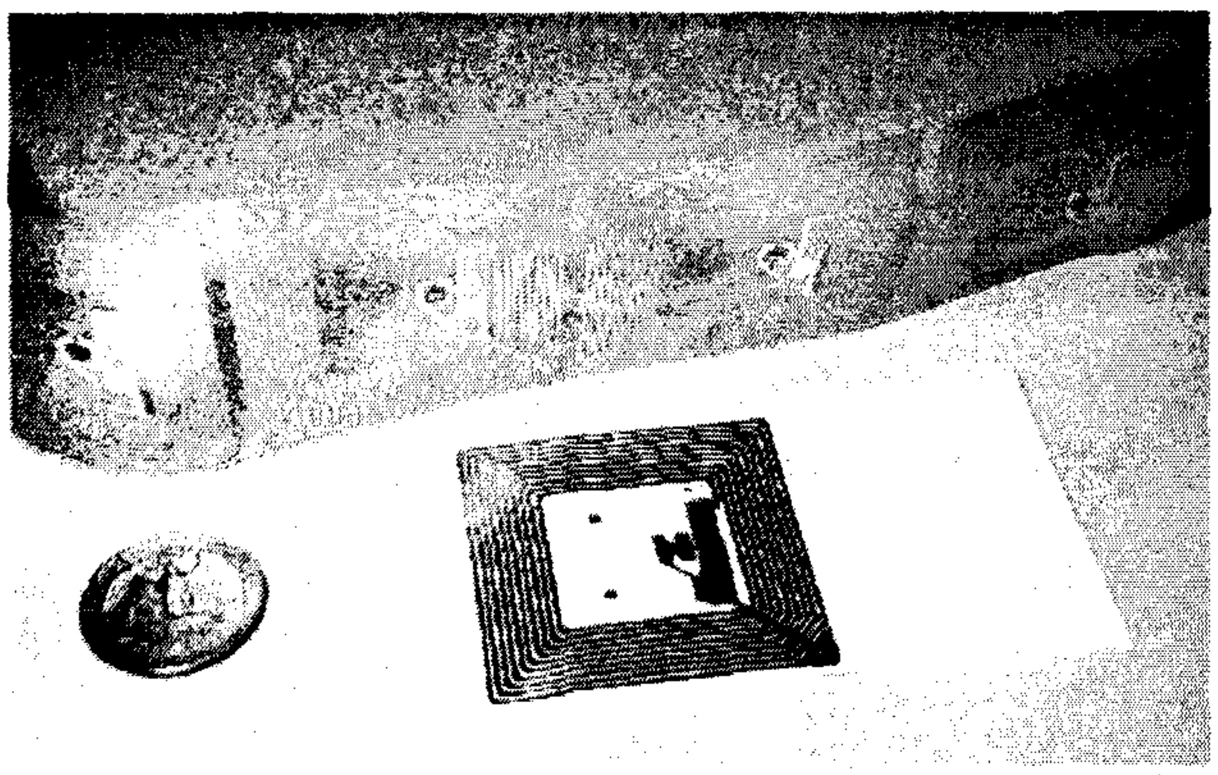


Figure 2. Tag It System by Texas Instruments (Source; http://dsonline.computer.org/archives/ds200/ds2wan.htm)

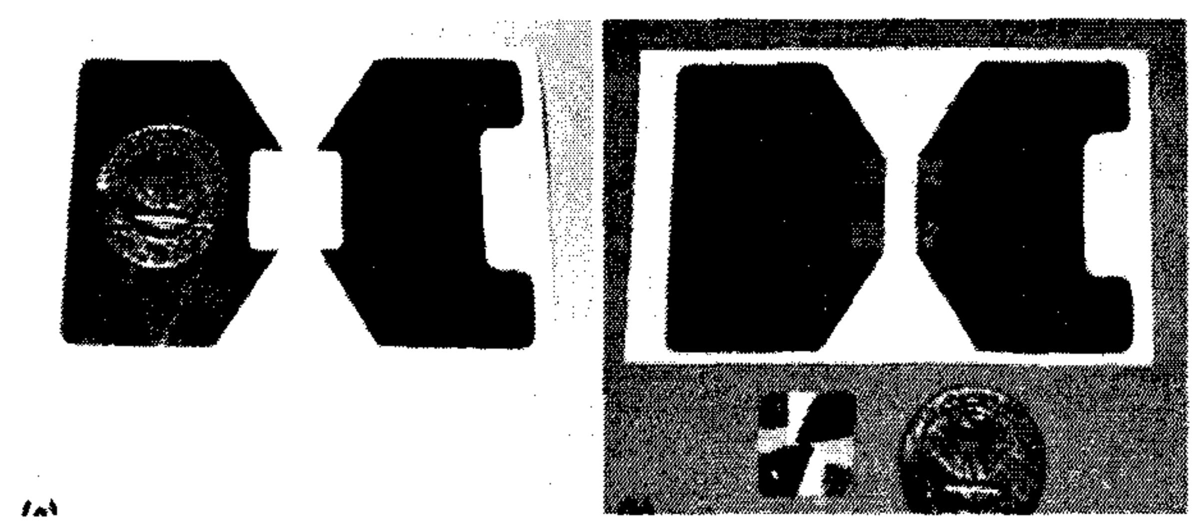


Figure 3. BiStatix Capacitive Coupled Tag (Source; http://dsonline.computer.org/archives/ds200/ds2wan.htm)

3. Sensors in Measuring Volume

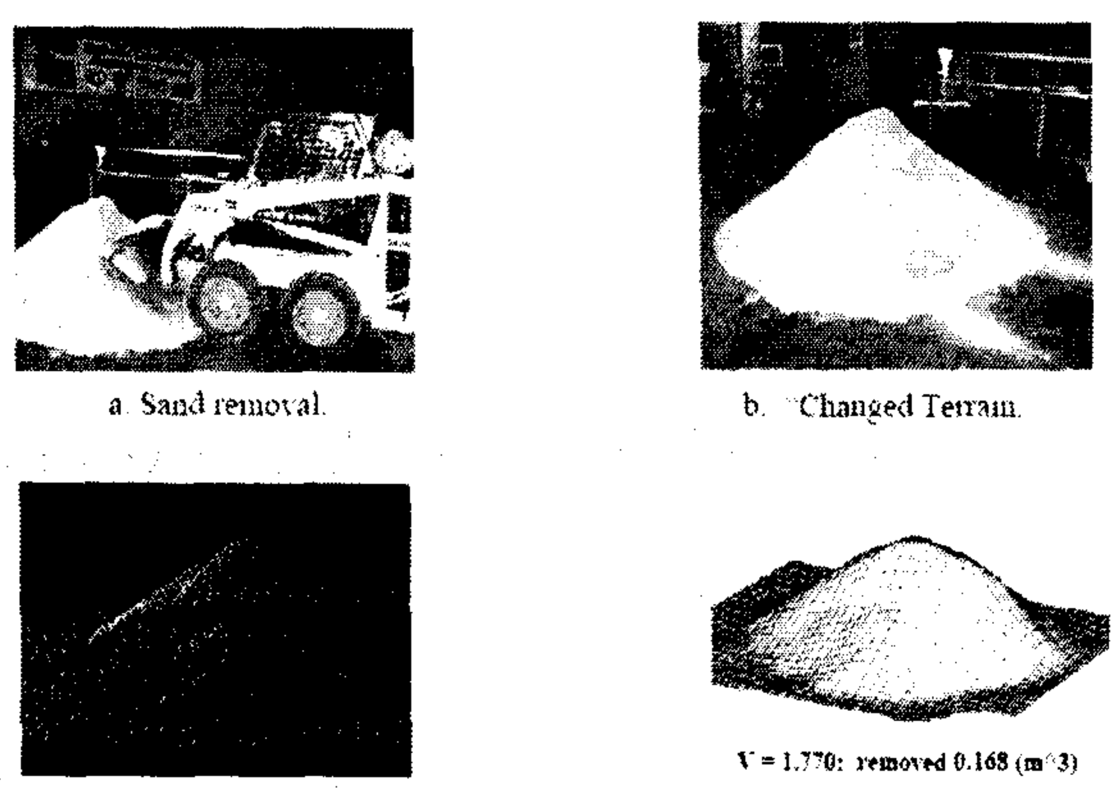
3.1. Laser scanning of material

The accurate assessment of the amount of materials moved has been one of the more difficult issues for construction planners or estimators to estimate productivity of operation. The fixed factor such as specific fill factor or load factor for material has taken into account when estimating productivity. These factors are derived from two sources; (1) historic data concurred through huge number of experiments and (2) standard references such as Caterpillar Performance Handbook. In addition to the amount estimation, the accurate assessment of the changed volume of soils has been required frequently for the accurate as-built data of an existing structure and information capable of providing real-time feedback for conducting operations.

The first process of measuring the volume of the stocked pile is to create the data which were three dimensional surface data generated by a laser scanner. These data were created based on the combination of the scanned data from four different positions (Cheok, et al. 2001).

When the change of amount of the stocked pile with adding or removal, the pile was rescanned from only one location or other locations. This rescanned data were compared with the original data registered before. The automatic calculation of volume is obtained from the changes as a result of comparing with original data and the rescanned data (Cheok, et al.2001).

Figure 4 shows this simulation described above.



a. Sand removal. b. Changed Terrain.

c. Rescan from one location d. Combined new scan with the three previous scans to regenerate the 3-D face.

Figure 4. Simulation of Calculation of the Changed Volume (Cheok, et al. 2001)

3.2. Sensors in measuring volumes in earthworks

Measuring methods of amount of soil moved by trucks are critical when the optimization of the performance of hauling trucks and the estimation of accurate productivity are demanding.

There are two kinds of targets of which material on trucks are measured: weight and volume. Trucks are specified the maximum weight to be hauled, thus engineers working on the equipment manufacturing industry are interested in how much weight trucks carry (Duff, 2000).

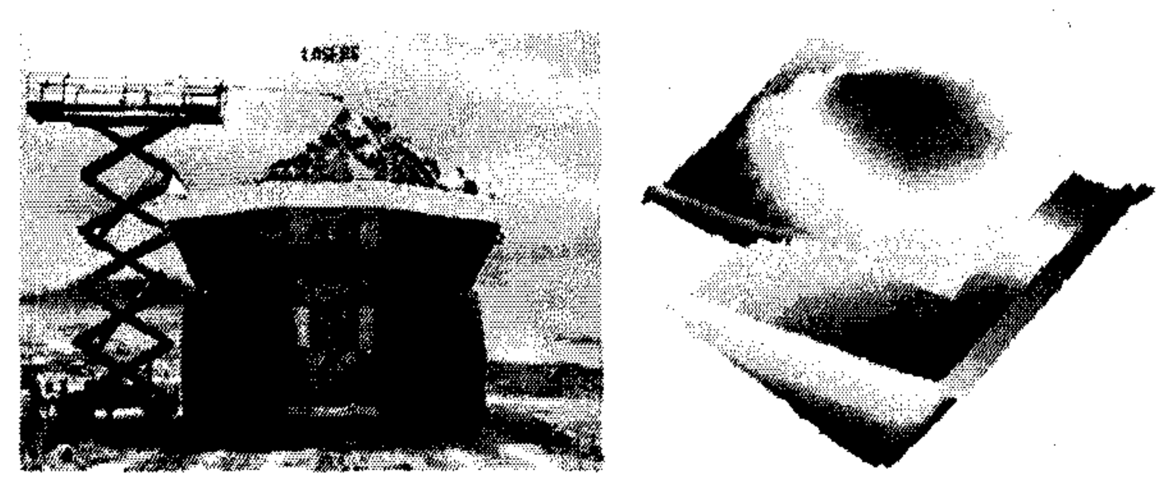
However, planners and estimators working on earthmoving operations are more interested in the soil volume to be cut or filled in construction.

Over the past, volumetric survey has been used for measuring soil volumes. With the development of laser scanning technology described earlier,

An automation group in CSIRO Manufacturing Science and Technologies in Austaralia created the new technology for directly measuringe the in-situ volume of material in the tray of each haul-truck. As hardware of this system, This system is composed of a computer and two instruments for scanning. The lasers are placed several meters above the trucks. When the truck moves under the lasers, a three dimensional profile is created automatically. After scanning of the soil on the truck's tray, the volume of the soil can be estimated by subtracting the three dimensional surface of the empty tray from the that of the full tray (Duff 2000).

Duff (2000) conducted the experiment to estimate the volume of material in each tray with application of laser scanning technology described above. This experiment demonstrated sufficient results within acceptable ranges.

Volume measurement system introduced in the paper by Duff (2000) is shown in Figure 5.



(a) Position of Lasers (b) 3D Laser Profile

Figure 5. Volume Measurement System by CSIRO (Duff 2000)

4. Global Positioning System (GPS) in construction

Many manufacturers in the construction industry have tried to find the new technologies which can be applicable to jobsite.

In recent years, the use of GPS in the construction industry has been not a surprise any longer. GPS technology has been introduced and developed to be used for achieving advantages such as automated control of equipment. For example, installing positioning sensors on construction equipment would provide construction companies with benefits like lower labor costs, and improvement of machine performance and work quality Accordingly, the GPS application to the construction has been considered as one of ways to increase job efficiency in construction jobsite.

The GPS which was developed for military usage at first is the one of the new technologies showing the high possibility to achieve the enhanced performance in the construction industry. As the first phase, the GPS was utilized to surveying requiring the high accuracy. The next phase is the application to the real positioning and guidance for construction vehicle. On the basis of the research of the GPS for positioning and guidance system, it has started in the past several years the GPS application to real construction jobsite focused especially on construction equipment.

According to the study by Peyret (2000), the GPS application to the construction equipment can be categorized into three main groups which differ based on requirements in terms of positioning:

- Earthmoving and mining equipment (e.g,, the big earthworks machines such as shovels, drills, scrapers, bulldozers, excavators, etc.).
- Surfacing equipment (e.g., the machines which move on the surface of the ground such as compactors, cement spreaders, mixers).
- Profiling equipment (e.g., the machines which modify the profile of the work site by addition or removal of material such as pavers, autograders, mining machines) (Peyret, 2000).

With the increase of various and huge construction projects, the systemized management of construction equipments has taken into account as the one of major factor. In this point of view, creating the system indicating real positioning of construction equipment in real time can be the first priority of the management on construction jobsite. That is, it would be the significant issue the notification of the location where the equipment are and the job what the equipment do in real time. The GPS has been selected with the reason of being able to accomplish the requirement describe above with the provision of the sufficient accuracy which is the most demanding in real time positioning and other traditional methods have never met to.

The GPS is a satellite-based positioning system, and it has been mainly used for surveying large areas and monitoring construction equipment or transportation vehicles. Differential GPS (DGPS) and On-The-Fly Differential GPS (O-T-F DGPS) are currently used in applications where better accuracy is required.

Haas (2000) suggested the real time positioning system, Computer Integrated Construction (CIC) system as a typical application of GPS positioning technology in his study (Hass 2000).

The CIC system consists of three main subsystems. As the first subsystem, a ground station provides geometric data about the target site as guidelines for equipment operation. These geometric data are saved in disk first. Then this disk is transferred to the machine where on-board subsystem is equipped. The second subsystem is a positioning system which is for providing the necessary position data to the system. This subsystem is located in ground within the range capable of covering the boundaries where on-board equipment is working. The third system is an on-board subsystem controling all the functions related to positioning with exchange of data on the machine itself (Hass 2000).

Figure 6 shows the basis architecture of a CIC system in the study by Haas (2000).

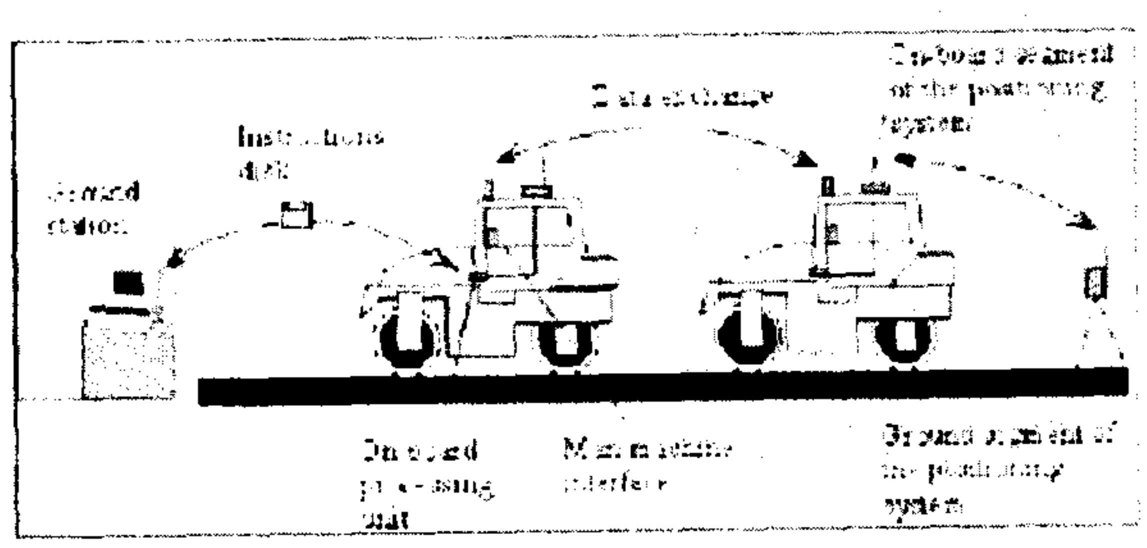


Figure 6. The basis architecture of a Computer Integrated Construction (CIC) system (Hass 2000)

It is recently proved that the GPS for real time positioning and guidance of construction equipment can provide the construction industry with competitive solutions for reaching to the required accuracy. In addition, the easy installation and usage of the GPS are other reasons why the GPS can be the alternative. The success of the GPS application to real time positioning and guidance system allows the application in construction jobsite to extend to various areas such as earthmoving and road construction and maintenance.

5. Conclusions

Recently, huge number of emerging technologies has been created and developed in other industries. It has been noticed that the construction industry has been so conservative to adopt new technologies comparing to other industries. This conservativeness is derived from the difficulty in using new technologies consistently to all jobsite. That is, each construction project is totally different with each other. Thus, the new technology which was proved to be efficient in a specific construction project may not be efficient in other construction projects.

This study reviewed specific aspects of three technologies; 1) the object identification, 2) the automatic volume measurement, and 3) the GPS, which have been presenting the high opportunities of wide applications to the construction industry especially focusing on construction data collection.

Electronic tags which were manufactured based on the object identification technology are introduced and developing continuously to the extent of capability to be used in outdoor especially construction jobsite.

The automatic volume measurement technology using the laser scanning technology presents the high opportunity to be used in earthmoving operation. The automatic measurement of the volume of materials to be moved allows planners and estimators to conduct the assessment of the more accurate amount of materials and finally to estimate the overall productivity of the current operations and further prospective operations.

The GPS has shown many benefits and opportunities to be utilized in surveying and real time positioning. The GPS has currently presented the application to other construction operations such as mining and earthmoving with provision of accurate positioning data and cut and fill volume in the construction equipment market. However, the higher costs for setting up at initial phase and technical errors caused by GPS technology must be resolved in order to accomplish the wider applications.

References

1. Cheok, G. S., Stone, W. C., Lipman, R. R., Witzgall, C., and Bernal, J., "Laser scanning for construction metrology." In Proceedings of American Nuclear Society 9th International Topical Meeting on Robotics and Remote Systems, Paper 082, 2001, pp. 1-9
2. Borriello, C., and Want, R., "Embeded computation meets the world-wide-web." CACM, Vol. 43, No. 5, 2000, pp. 59-66, <http://citeseer.nj.nec.com/borriello99embedded.html> (12, September, 2003)
3. Duff, E., "Automated volume measurement of haul-truck loads." Research paper of CSIRO manufacturing Science and Technology, 2000, <www.dem.csiro.au/mining_automation/research/projects/haultruck/documents/haultruck.pdf>, <www.cat.csiro.au/cmit/automation/projects/occo00.pdf>, and <http://www.dem.csiro.au/mining_automation/research/projects/haultruck/> (12, September, 2003)
4. Everett, J. G., Halkail, H., and Schlaff, T. G., "Time-lapse applications for construction project management." Journal of Construction Engineering and Management, ASCE, Vol. 124, No. 3, 1998, pp. 204-209.
5. Gili, J. A., Corominas, J., and Rius, J., "Using Global Positioning System techniques in landslide monitoring." Engineering Geology, Vol. 55, No. 3, 2000, pp. 167-192
6. Hass, C. T., "Automation in transportation system construction and maintenance." Transportation research E-CIRCULAR, Number:E-C017, 2000, <http://www.nas.edu/trb/publications/circulars/ec017.pdf> (07, February, 2002)
7. Kannan, G., "A methodology for the development of a production experience database for earthmoving operations using automated data collection." Ph. D. Dissertation of Civil Engineering in Virginia Polytechnic Institute and State University, 1999
8. Krishnamurthy, B.K., "Towards an automated paving system for asphalt pavement compaction operations." Master Thesis, Univ. of Wisconsin-Madison, 1996.
9. Krishnamurthy, B.K., Tserng, H.P., Schmitt, R.L., Russell, J.S., Bahia, H. U., and Hanna, A. S., "AutoPave: towards an automated paving system for asphalt pavement compaction operations.", Automation in Construction, Vol. 8, No. 2, (1998), pp. 165-180.
10. Oglesby, C. H., Parker, H. W., and Howell, G. A., "Productivity improvement in construction." McGraw Hill, Inc., 1989
11. Oloufa, A., Do, W. S., & Thomas, H., "Automated monitoring of compaction using GPS." In Proceedings of ASCE Construction Congress V, 1997, pp. 1004-1011
12. Peurifoy, R. L., Ledbetter, W. B., and Schexnayder, C. J., "Construction planning, equipment, and methods." McGraw Hill, Inc., 1996
13. Peyret F., Bétaille D., and Hintzy G., "High-precision application of GPS in the field of real-time equipment positioning." Automation in Construction, Vol. 9, No. 3, 2000, pp. 299-314
14. Peyret, F., "The computer integrated road construction project." Automation and Robotics in Construction XVI, 1996, pp. 593-598
15. Peyret, F., "A new facility for testing accurate positioning systems for road construction robotics." Automation in Construction, Vol. 8, No. 2, 1998, pp. 209-221
16. Peyret, F., "The paragigm of computer construction applied to civil engineering." Automation and robotics in construction XVI, 1999, pp. 3-9
17. Schaufelberger, J. E., "Construction equipment management." Prentice Hall, Inc., 1999

18. Vogt, H., "Efficient object identification with passive RFID tags." In Proceedings of international conference pervasive computing, LNCS. Springer-verlag, Zurich, Switzerland, 2002
19. Want, R., Fishkin, K., Gujar, A., and Harrison, B., "Bridging physical and virtual worlds with electronic tags." In Proceedings of ACM CHI '99, 1999, <http://citeseer.nj.nec.com/want99bridging.html> (12, September, 2003)
20. Want, R., and Russell, D. M., "Ubiquitous electronic tagging." IEEE Distributed Systems Online, Vol. 1, No. 2, 2000, <http://citeseer.nj.nec.com/context/1761857/0> and <http://dsonline.computer.org/archives/ds200/ds2wan.htm> (27, October, 2003)