RFID Positioning Algorithm

Chien-Ho Ko [1]

Abstract

Effective monitoring of personnel movements, material locations, and construction equipment has always been a topic of concern in construction management. Radio Frequency Identification (RFID) technology has been proven to increase efficiency for staff and materials management. The objective of this study is to develop a Three-Dimensional (3D) positioning algorithm using RFID technology to analyze the possible location of objects. To achieve this goal, this research first establishes an indoor wireless sensing network to collect Received Signal Strength Indication (RSSI). The distance between the antenna and target tag is calculated based on RSSI. The gradient decent method is then used to calculate the location of the electronic tag. The feasibility of this 3D positioning algorithm is verified using a real case. The experiment proves that the positioning algorithm established in this study can gradually approach the actual location of the target tag. This research is one of the lead-in studies for 3D positioning with RFID application in the construction industry. The proposed RFID 3D sensing algorithm can be used to assist construction managers in locating the positions of relevant personnel, equipment, apparatus and materials, enhancing management efficiency.

Keywords: Radio Frequency Identification (RFID) Technology, Three-Dimensional (3D) Space, Positioning.

Introduction

The construction industry must manage large numbers of construction workers, costly materials, and a variety of construction equipment. To successfully manage projects, the construction manager requires effective monitoring of personnel movements, material locations, and construction equipment (Ibn-Homaid 2002, Fan et al. 2008). RFID is one of the major technologies of the twentieth century (Hunt et al. 2007), owing to its durability, rewritability, rich data capacity, and contactlessness, which has become a new technology for enhancing construction management (Fontelera 2005).

In recent years, researchers have actively used RFID technology in positioning. Lionel et al. (2004) pointed out that active RFID system application in indoor positioning is a viable and economical option. Yun et al. (2006) applied a wireless RFID network in iron and steel plants to detect the location and movement of personnel to avoid hazards. They showed RFID feasibility in displaying real-time personnel locations and movement, thus reducing hazards. However, previous studies mostly described one-dimensional or two-dimensional positioning, and are not applicable in seeking objects in three-dimensional (3D) space (Ko 2010). The objective of this study is to develop a RFID 3D positioning algorithm using RFID technology with spatial information analysis.

Radio Frequency Identification (RFID) Technology

RFID technology is a wireless sensor technology based on electromagnetic signal detection (McCarthy 2003). One of the earliest papers exploring RFID was written by Harry Stockman

[1] Professor, Department of Civil Engineering, National Pingtung University of Science and Technology, 1, Shuefu Road, Neipu, Pingtung 91201, Taiwan, Tel: +886-8-7703202, Fax: +886-8-7740122, E-mail: ko@npust.edu.tw.

‘‘Communication by Means of Reflected Power’’ published in 1948. A typical RFID system, as shown in Figure 1, is comprised of three components: an antenna, a transceiver, and a transponder. Figure 1 shows that the transponder (RF tag) is electronically programmed with unique information. Radio signals are emitted by the transceiver through the antenna. Antennas establish communication between the tag and transceiver. The RF tag transfers data according to a specific request. The transceiver is responsible for data acquisition. The data can then be transferred to any computer system for processing (Domdouzis et al. 2007). The antenna can be packaged with the transceiver into a reader/writer unit. The reader/writer can be implemented either as a handheld or fixed-mount device. The radio wave ranges emitted from the device depends on the power output and radio frequency.

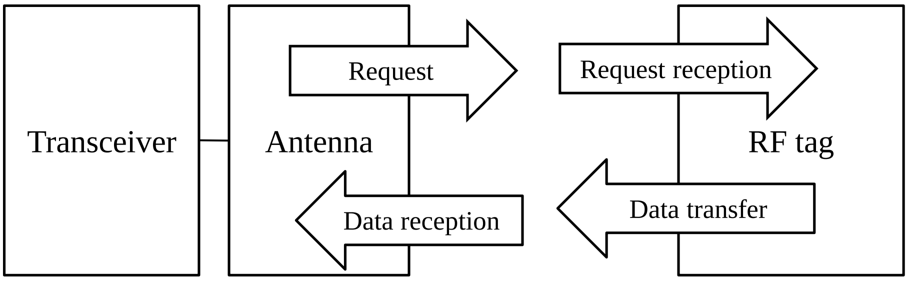

Figure 1. RFID Schema

Positioning Method

The trilateration location concept is illustrated in Figure 2. This concept requires at least three signal transmission towers. The system needs to know the locations of these towers. Assuming that the signal emitted by each node is in the range covered by the circles in the figure. The signal tower coordinates, for example, are (X = 0, Y = 0), (X = 2, Y = 0), and (X = 1, Y = 1). The range covered by the three nodes are r1, r2, and r3. The location of an unknown object could be calculated utilizing the intersecting range from the three nodes (Holger and Willig 2005). If this concept is applied with more than four signal transmission towers, this location concept is called multi-lateration.

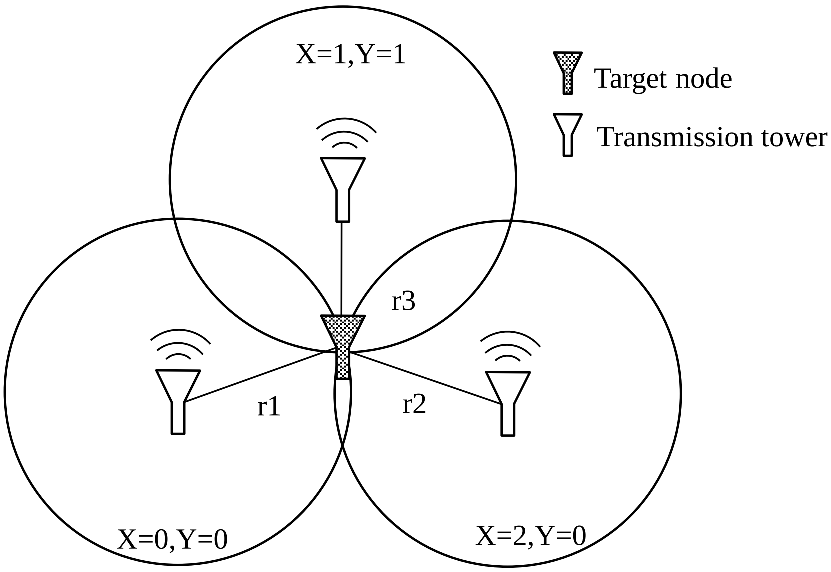

Figure 2. Location Concept

RFID positioning can be implemented in an active or passive mode. In the active location mode, the target location is installed with an antenna. The location space is supplied with passive RFID tags (Reference tags). After the target location transmits a signal to the surrounding reference tags, the coordinates of the object are calculated based on the reference tag coordinates. Under this mode the target location is installed with a RFID antenna and this must be in conjunction with a large number of reference tags in order to identify a location. In addition, if the target is too far away from the reference tags or surrounded by an insufficient number of reference tags, the location error would increase dramatically.

3D Positioning

This study uses the trilateration location concept coupled with RFID technology to design a 3D positioning algorithm. In 3D space, if only a single RFID antenna is used for location, the obtained target location would be a sphere. If an additional RFID antenna is used, the target location can be limited to the intersection of two spheres, namely, an arc line. Based on wireless sensor networks if a third antenna is placed, there would be two points of intersection with this single arc line (as shown in Figure 3). These two points are representative of the two possible locations of the target location. In order to seek a reasonable solution, this study used a fourth antenna to obtain the unique location of the target in 3D space, as displayed in Figure 3. The positioning algorithm established in this study supports four antennas to conduct 3D positioning.

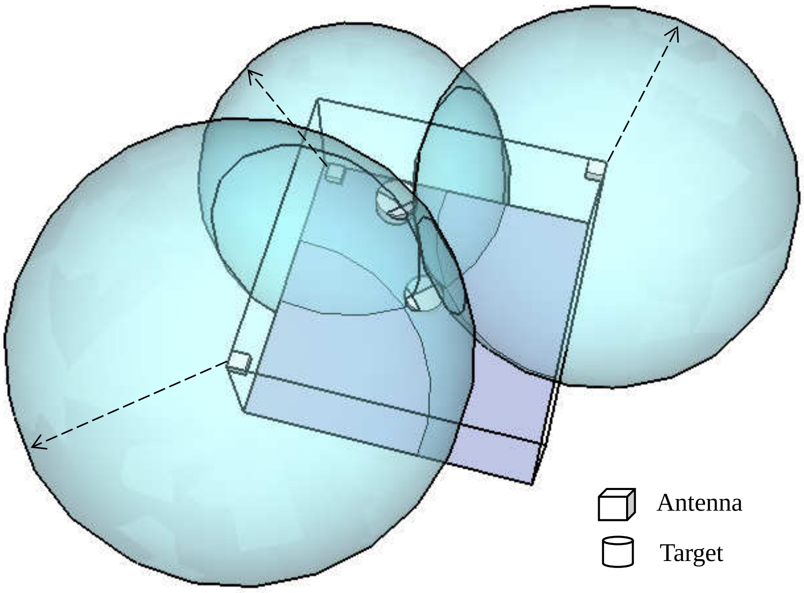

Figure 3. Location with Three Antennas

The RFID 3D positioning algorithm developed in this study utilizes the gradient descent method based on an error function to calculate the possible location coordinates. The initial position for the first step of the algorithm can be chosen by random generation, human subjective decision, or calculated from the center of the location space. The center of the location space, noted as (x_c, y_c, z_c), is a point in the half-way for the x, y, z, axes, which can be calculated using Eq. (1).

$$(x_c, y_c, z_c):\begin{cases} x_c = \dfrac{(x_i - x_e)}{2} \\ y_c = \dfrac{(y_i - y_e)}{2} \\ z_c = \dfrac{(z_i - z_e)}{2} \end{cases} \quad (1)$$

where x_i and x_e denotes initial and end points of x coordinates for location space; y_i and y_e denotes y coordinates and so forth.

The distance between RFID antenna and tag is calculated by employing the radio-frequency signal attenuation with distance principle. To obtain the relationship between RSSI and distance for a specific location space, the relationship between the reference tag distances and RSSI namely, Wireless Signal Attenuation Curve (WSAC), is used to calculate the distance between the RFID antennas and target tags.

Experiments

To verify the performance of the proposed RFID 3D positioning algorithm, an actual case was carried out in a location space (926 cm in length, 535 cm in width, and 211 cm in height). The actual target tag coordinate is (694cm,400cm,75cm). This experiment first set the initial coordinate as (1,1,1) with adjustment values $\alpha_x = \alpha_y = \alpha_z = 5\times10^{-5}$. The convergence trend is shown in Figure 4. In the figure, x, y, and z represents the tracing values in the searching process of 3D location algorithm. Since the initial location x and y-axis are relatively far away from the actual coordinate, the convergence process prior adjusts the x and y-coordinate of the target tag. Once the x and y-axis become stabilized, the algorithm begins convergence along the z-axis. The algorithm gradually converged from the initialized point to the actual target location, which proves that the gradient descent method can be successfully applied in spatial positioning.

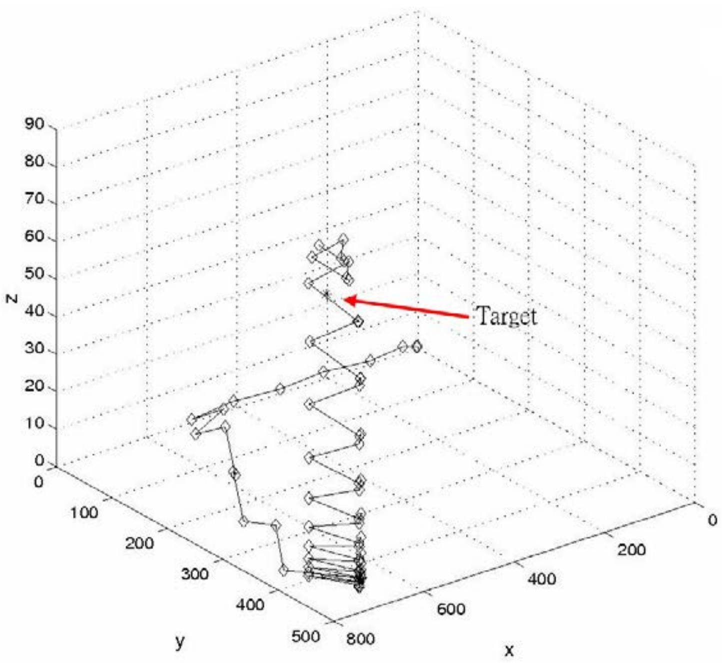

Figure 4. Experimental Results

Conclusions

This study reveals the potential for 3D positioning RFID technology for further implementation to the navigational needs of construction management, such as equipment, apparatus, and materials monitoring. In addition to asset tracing, the proposed algorithm can be applied to personnel safety management for improving project management efficiency.

The signal attenuation effect caused by the surrounding environment was not taken into consideration in this study. However, signal attenuation experiments are planned in the future for spatial positioning algorithm adjustment.

Acknowledgments

This research was funded by the Architecture and Building Research Institute (ABRI) and Ministry of Science and Technology (MOST), Taiwan with grant number NSC 99-2622-E-020-006-CC3, whose support is gratefully acknowledged. Any opinions, findings, conclusions, or recommendations expressed in this paper are those of the author and do not reflect the views of the ABRI and MOST.

References

Domdouzis, K., Kumar, B., Anumba, C. 2007. Radio-Frequency Identification (RFID) applications: A brief introduction. *Advanced Engineering Informatics*, 21(4), 350-355.

Fan, H., Kim, H., AbouRizk, S., and Han, S.H., 2008. Decision support in construction equipment management using a nonparametric outlier mining algorithm. *Expert Systems with Applications*, 34(3) 1974-1982.

Fontelera, J. 2005. RFID exploration, *Converting Magazine*, 23(9) 28-32.

Hunt, V.D., Puglia, A., and Puglia, M., 2007. *RFID-A Guide to Radio Frequency Identification*, Wiley-Interscience.

Holger, K., and Willig, A. 2005. *Protocols and Architectures for Wireless SensorNetworks*, John Wiley & Sons.

Ibn-Homaid, N.T., 2002. A comparative evaluation of construction and manufacturing materials management. *International Journal of Project Management*, 20(4) 263-270.

Ko, C.H. 2010. RFID 3D location sensing algorithms. *Automation in Construction*, 19(5) 588-595.

Lionel, M.N., Liu, Y.H., Lau, Y.C., and Patil, A.P., 2004. LANDMARC: Indoor location sensing using active RFID. *Wireless Networks*, 10(6) 701-710.

McCarthy, J.F., Nguyen, D.H., Rashid, A.M., Soroczak, S. 2003. Proactive Displays & The Experience UbiComp Project. *Proceedings of the Fifth International Conference on Ubiquitous Computing*, 78–81.

Stockman, H. 1948. Communication by Means of Reflected Power. *Proceedings of the Institute of Radio Engineers*, 36(10) 1196-1204.

Yun, K., Choi, S., and Kim, D. 2006. A robust location tracking using ubiquitous RFID wireless network, Lecture Notes in Computer Science. *Proceedings of the Third International Conference on Intelligence and Computing*, 113-124.