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A Consideration of Accuracy Correction Methods in RTLS for Indoor Facility Management with Drones

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Abstract: The construction industry has witnessed an exponential growth of drones used in the field over the past few years. Likewise, the field of maintenance has paid increasing attention to using drones with a view to improving the efficiency of condition checks in high-rise buildings and major space. Although operators manipulate drones to inspect buildings at present, drones are expected to autonomously move around without operators in a few years. Also, for indoor maintenance, it is important for drones to find accurate locations, which is implemented by real-time locating systems(RTLS). Yet, the accuracy of RTLS varies across the types of systems and indoor settings, which warrants a locating system suitable for indoor space and a location correction system designed to improve the accuracy. Hence, the current study investigated the accuracy of real-time locating systems(RTLS) for the maintenance of indoor space of buildings with drones and delved into the methods of correcting the location information to improve the accuracy of RTLS.

Key words: RTLS, Facility Management, Drone, Indoor

1. INTRODUCTION

The use of unmanned aerial vehicles(UAVs), or drones, has exponentially increased in the construction industry over the past few years(ENR 2015). The rapid advancement of sensing, battery and space technologies have made self-driving UAVs and digital cameras more affordable and reliable and easier to manipulate(Liu et al., 2014). Today, service providers in the architecture, engineering and construction/ facility maintenance (AEC/FM) industries use the foregoing platforms to visually monitor the construction and operation of buildings, bridges and other types of facilities[13. Operating drones has many advantages in inspecting and collecting data from hard-to-reach spots such as roofs and ceilings, and the data collected as such helps facility managers to effectively detect any defects [7]. Also, it is highly dangerous and costly for inspectors to check large-scale buildings with devices in person. Yet, using drones, infrared thermal cameras and diverse sensors simultaneously reduces the safety risks that may arise in those buildings, and accelerates the inspection process[11]. In addition, self-driving UAVs will become available in a few years although most UAVs are now remotely controlled by humans on the ground. As a result, drones will improve the efficiency and cost effectiveness of maintenance, while their importance will keep growing.

Meanwhile, real-time locating is used for property management, facility management and building maintenance. For example, real-time locating helps managers shorten the time taken for property search, enhances the efficiency of property management, and also helps residents unfamiliar with buildings find their destinations[3]. In addition, real-time locating helps manage energy and ventilation in accordance with occupants' real-time locations indoors[9]. Furthermore, real-time locating helps find building components for maintenance and supports maintenance works[10]. Due to the foregoing advantages, using indoor location information in building maintenance has drawn much attention. Still, the accuracy of real-time locating systems varies across the types of systems, dynamic/static states, and conditions of buildings [5]. Particularly, the accuracy is low indoors. As indoor environment is complex, even when using identical systems and methods, the accuracy varies with locations. Thus, even when the coordinates of the targets to be observed are accurate, drones often fail to reach the intended locations and to capture the targets accurately. To use drones for the maintenance of indoor space of buildings, a method of correcting the errors of RTLS is needed. Hence, the present study investigated the existing real-time locating systems and their accuracy, and explored the methods of correcting their errors to increase the accuracy of location information.

2. Accuracy of RTLS

Real-time locating systems (RTLS) include RFID, GPS, UWB and WLAN, with the accuracy of locating varying across dynamic and static states and the presence or absence of obstacles[12].

1) RFID

RFID systems are low-cost location systems conducive to non-line-of sight settings, and consist of RFID readers and tags. RFID readers transmit RF signals, while response tags add information with modulation and reflect the signals. Tags are active and/or passive, and support mobile devices with indoor locating. Passive tags have no batteries and can be used permanently. Passive tags are inexpensive but operate within a limited range. By contrast, active tags with batteries support much wider ranges. RFID systems are generally used in complex indoor environment such as offices, buildings and hospitals, as a quite inexpensive and flexible approach to identifying persons and devices. The accuracy of RFID systems varies across study methods. Still, Motamedi and colleagues reported an error of 0.28m in an RFID system[2].

2) GPS

GPS gains the location(x,y,z) of a receiver with triangulation. The location is computed based on the distance from a satellite to a GPS receiver, the time taken for a GPS signal to travel from the satellite to the receiver and the light speed. The accuracy of GPS varies. Teizer[8] tested a method of locating a device using GPS, and found a mean error of 1.1m in open space, whilst the error increased to 2.15m and 4.36m when obstacles were present nearby. Notably, GPS suffers a rapid attenuation of signals indoors, hardly lending itself to indoor use.

3) UWB

UWB location systems are inexpensive but noteworthy for better power efficiency, higher temporal resolution and robustness against the multipath fading of UWB signals. UWB location systems consist of reference nodes whose locations are known and active tags whose locations are estimated. Also, with short UWB pulses, it is possible to filter the reflected signals from the original signals so as to overcome the multipath distortion of indoor environment, and provide more accurate results. UWB has a mean error of 50cm or less. To accurately estimate the locations of tags, four reference nodes are needed. Still, additional reference nodes are required to increase the accuracy[6].

4) WLAN

In WLAN, the existing WLAN may be reused. In general, locations of objects are computed based on the signal strength. Woo. et al[12] used a WiFi-based WLAN positioning system to compute the locations of workers, and found errors of 6.89㎛ and 4.53㎛ in vertical and horizontal directions, respectively, with static WLAN, whereas dynamic WLAN led to errors of 0.63m ~ 5.92m. These errors varied with wireless network frequencies, signal strength, equipment and directions.

5) Ultrasonic

Ultrasonic locating systems are characterized by low-cost systems, stability, scalability and high energy efficiency in comparison to other locating systems. Ultrasonic locating systems ensure a centimeter-level accuracy of locations, and track multiple mobile nodes at once. That is, high capacity systems can provide location information for multiple users simultaneously. Ultrasonic location systems depend on TOF measurements of US signals computed based on the sound speed. Still, unlike RF signals, the sound speed in the air is far from constant, and substantially varies with surrounding conditions such as humidity and temperature. High humidity causes US signals to fade faster and travel shorter distances. The accuracy and precision of ultrasonic systems vary with the waiting time and update speed. Yet, ultrasonic systems cannot penetrate walls, and are susceptible to distortion resulting from noises due to reflected signals and metal objects[4].

As discussed so far, given the accuracy of real-time locating systems varies across types of systems and surrounding environment, it is necessary to apply appropriate real-time locating systems by taking into account the conditions and environment of buildings before using such systems for building maintenance.

3. Methods of correcting location information

To improve the accuracy of location information, such methods as combining the probabilistic model including fingerprint, enhancing the signal strength of transmitters, and increasing the number of transmitters may be used. The current study explored Dead Reckoning and IMU for correcting the accuracy of location information to generate more accurate location information instead of the methods of adjusting the signal strength and increasing the number of transmitters.

1) Correction with Dead Reckoning

Dead Reckoning is a locating technique based on the estimation of travel patterns or the integration of distance vectors. In general, the change of directions is measured with a gyroscope, whose rotational velocity is crucial for the inertial navigation system. The travel distance is measured with an odometer, which is an electronic device generating a digital pulse upon each rotation of the wheel and capable of estimating the distance. Ming Lu and three colleagues used Dead Reckoning, Beacon(a short-distance communication system using low-power Bluetooth within a 50~70-meter radius), and GPS to develop a system for locating the trucks on site, and reported an error of 2.4m minimum[6].

2) Correction with IMU(Inertial Measurement Unit)

As a rule, an IMU is comprised of two orthogonal sensor triads. One triad consists of 3 single-axis accelerometers, while the other consists of 3 single-axis gyroscopes. The two triads are Parallel, while the starting point of the gyroscope is defined as the starting point of the accelerometer triad. The primary disadvantage of the IMU involves biases and scale factors. To increase the accuracy of locations, it is necessary to analyse the sensor operation and to conduct a special correction for testing under static and kinematic conditions. A.Benini and 3 colleagues used UWB communication and IMU to develop an indoor locating system, which was tested in an indoor space with an error of less than 15cm[1].

4. Conclusion

The advantages of drones and real-time locating systems have driven a wide range of R&D efforts to apply them to building maintenance. Yet, the accuracy of real-time locating systems varies with the types of such systems, dynamic and static states and conditions of buildings [6]. Particularly, the accuracy is lower indoors. As the indoor environment is complex, the accuracy of even identical systems and methods varies with locations. To address the challenges relevant to the accuracy of such systems, this study examined the concepts and accuracy of different real-time locating systems for applying drones to indoor space maintenance. Also, for accurate real-time locating, this study analyzed the methods of correcting the locations reported in previous studies.

Real-time locating systems include RFID, GPS, UWB, WLAN and Ultrasonic systems. The ultrasonic locating systems are most accurate, but cannot penetrate walls. The UWB-based locating systems are second most accurate. Also, the most widely used GPS systems have an accuracy of 1.1m in open space, but are not available indoors due to severe signal attenuation.

The accuracy of location information may be improved by altering the method of computing the location information, adjusting the signal strength, or increasing the number of transmitters. Still, the present study delved into Dead Reckoning and IMU for correcting the accuracy of location information, instead of the adjustment of signal strength or the addition of transmitters. Both Dead Reckoning and

IMU are capable of correcting the location information to improve the performance of location measurement systems. According to the previous studies reviewed here, the correction using UWB communication and IMU sensors proved to be most accurate with an error of less than 15cm. However, given the significant difference in accuracy between GPS and UWB, further studies need to compare the methods of using the currently most accurate locating system UWB in tandem with IMU and Dead Reckoning, respectively.

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