ISSN: 2278 – 909X
International Journal of Advanced Research in Electronics and Communication Engineering (IJARECE)
Volume 1, Issue 3, September 2012

A Novel Approach for Mobile Robot Localization Using Wireless Sensor Fusion

Atluri Samyuktha[1] Kavuri Vijaya Chandra[2] S.V.Srinivasaraju[3]
[1]PG Student, prakasam engg. College,Kandukur,Prakasam (Dt)
[2]Associateprofessor,prakasamengg.college, Kandukur,Prakasam (Dt)
[3]AssitantProfessor,Narasaraopetengineeringcollege,Narasaraopet,Guntur(dt)

Abstract—This paper addresses a radio-frequency identification (Zig-Bee)-based mobile robot localization which adopts Zig-Bee tags distributed in a space. Existing stand-alone Zig-Bee systems for mobile robot localization are hampered by many uncertainties. Therefore, we propose a novel algorithm that improves the localization by fusing an zig-Bee system with an ultrasonic sensor system. The proposed system partially removes the uncertainties of RFID systems by using distance data obtained from ultrasonic sensors. We define a global position estimation (GPE) process using an Zig-Bee system and a local environment cognition (LEC)process using ultrasonic sensors. Then, a hierarchical localization algorithm is proposed to estimate the position of the mobile robot using both GPE and LEC. Finally, the utility of the proposed algorithm is demonstrated through experiments.

Index Terms—Localization, mobile robot, obstacle estimation, radio-frequency identification (RFID),Zig-Bee, sensor fusion.

I. INTRODUCTION

The infrastructure for building a sensor network, which is a basic element of the digital ecosystem, is growing rapidly [1], [2]. In recent years, a sensor network without limitations of time, place, and situation has been applied to several areas [3]–[7]. Mobile robots based on sensor networks are a typical example of this application. Mobile robots can offer services using a sensor network that has been built into indoor spaces such as offices, homes, and airports. The sensors and robots that are distributed within a space constitute the digital ecosystem. It has been predicted that indoor mobile robots will be human-friendly robots that interact with people [8], [9]. To ensure the safety and stability of human–robot interaction, more accurate and precise mobile robot localization systems are essential. The classical localization system for mobile robots uses dead-reckoning sensors such as encoders and gyroscopes [10], [11]. Other systems use some combination of cameras, ultrasonic sensors, and the GPS [12]–[14]. However, the dead- reckoning sensors are subject to accumulation errors that can result in inaccurate performance for cases involving large displacements. The other types of sensors are constrained by environmental factors such as illumination in the case of charge-coupled device (CCD) cameras and outdoor conditions for the GPS. These problems in the classical method translate into uncertainties that diminish the accuracy and precision of mobile robot localization. In order to reduce these uncertainties, researches have been conducted on the applications of sensor networks for mobile robot localization. Several studies have adopted radio-frequency identification (RFID) technology for sensor networks [15]–[18]. Practical features of Zig-Bee technology include the following:1) storage of location and environment information within Zig-Bee tags; 2) classification of information using private identification (ID) codes; 3) convenient approach to information; and 4) robustness under environmental changes. Exploiting these features, we can implement a new forming localization system that can address the deficiencies in conventional localization systems. However, RFID systems suffer from technical limitations not unlike those found in conventional systems. The target of this research is a mobile robot localization applying Zig-Bee technology, which uses distributed Zig-Bee tags.We propose a novel algorithm to overcome uncertainties in previous Zig-Bee systems for mobile robot localization. We focus on a sensor fusion that uses an Zig-Bee system and ultrasonic sensors. Localization using a single sensor system cannot guarantee accuracy due to limitations from the system. Thus, ultrasonic sensors and the Zig-Bee system are used to complement one another and compensate for each other's limitations. Therefore, a hierarchical localization system is proposed for efficiently using and integrating data obtained from arbitrary environments from each sensor.The remainder of

All Rights Reserved © 2012 IJARECE

this paper is organized as follows. In Section II, we address related works and problems to solve.In Section III, the global position estimation (GPE) process using the Zig-Bee system is explained. In Section IV, the local environment cognition (LEC) process using ultrasonic sensors is explained. In Section V, the hierarchical algorithm for mobile robot localization using GPE and LEC is explained. Finally, we conclude this paper in Section VI.

II. Related Works and Research Objectives

A. Localization of Zig-Bee Based on RFID System:

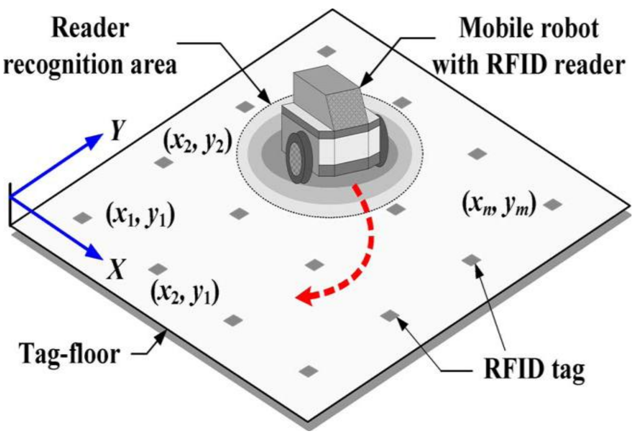

Fig. 1. RFID system based on tag floor for the mobile robot localization,

which adopts RFID tags distributed in a space RFID systems have several features and functions that depend on the frequency band, nature of the power source, tags, etc. Therefore, many localization methods and applications exist in the literature [19]. This paper discusses an RFID system based on a tag floor using passive RFID tags for mobile robot localization, which is addressed in [15] and [20]. Passive RFID tags are arranged in a fixed pattern on the floor, and absolute coordinate values are stored in each tag to provide the position data to the mobile robot, as shown in Fig. 1. An RFID reader (connected to an antenna) is installed underneath the mobile robot for reading the data from the RFID tags. If the robot moves to a position over an RFID tag, the RFID reader reads the coordinate value of the RFID tags to localize the mobile robot. The absolute location of the mobile robot on the floor is estimated without consideration of obstacles or landmarks. The representative problem of the aforementioned system is that the accurate position and distances between the RFID reader and the RFID tags are not measured. If the RFID tags are found within the reader recognition area, their existence can be just checked. Position estimation errors are thus generated according to the gap between the tags and the reader recognition area. Other problems and uncertainties are fully explained in Section III.To date, several algorithms have been proposed to solve these problems. Ma and Kim [20] proposed the aforementioned scheme employing a tag arrangement pattern; this method depends on the mobile robot travel path. Hahnel *et al.* [21] and Seo *et al.* [22] used a probabilistic based filter. However, the estimation error increases when no new RFID tags are found. Statistical and probabilistic methods cannot solve the problem rooted in system limitations. In other studies, a triangular arrangement of RFID tags was proposed to reduce the estimation error [23]. However, since this method depends on the gap between the tags, increasing numbers of RFID tags must be used to reduce errors. Further studies examined encoder sensor systems used to compensate for limitations in RFID systems [24]. However, it was found that the error accumulation resulting from wheel slippage may cause the robot to veer off its intended course over long distances. CCD cameras have been used in the fusion system, but these systems are often hampered by illumination problems [25]–[27].These previous works tried to solve the problem through the temporary exclusion of uncertainties without the direct consideration of the uncertainty associated with RFID systems. Therefore, localization is only efficient in cases where the mobile robot drives along a specific path and for cases where RFID tag information is given continuously.

All Rights Reserved © 2012 IJARECE

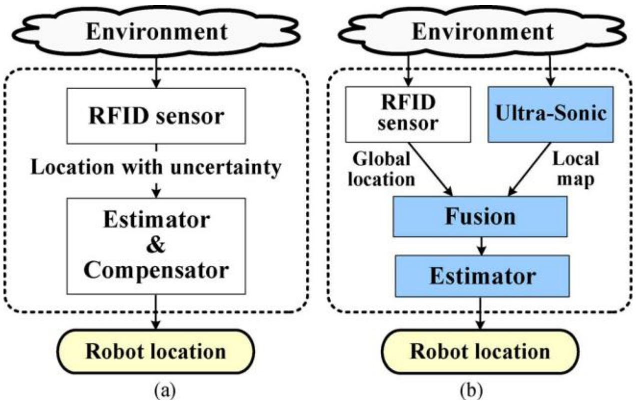

Fig2. Differences between the previous system and proposed localization system. (a) Conventional localization system architecture based on RFID technology. (b) Proposed system architecture based on RFID fusion sensor.

B. Research Objectives

In this paper, the problems shown in existing studies are considered, and possible solutions are proposed. We present a localization system based on the sensor fusion between an RFID system and ultrasonic sensors. As discussed earlier, the ultrasonic sensors can compensate for the limitations and uncertainties in existing RFID systems.We describe and add a model addressing the uncertainties associated with measurement noise in the RFID system. We assume the mobile robot traveling environment to be a well-structured indoor environment. To reduce the uncertainty associated with measurements from the ultrasonic system, we consider only primitive geometrical objects:straight with regular inclination and circular with regular curvature. We define a GPE process via the RFID system and a LEC process via ultrasonic sensing. We propose a hierarchical localization algorithm to estimate the mobile robot position from GPE and LEC.

III. GPE

A. Uncertainty of RFID System over zig-bee

In Section III, the process of finding the global position of the mobile robot via an RFID system is defined as GPE.

First, we consider the uncertainty of the RFID system when applied for mobile robot localization. The RFID system based on a tag floor estimates the position of the mobile robot through the coordinate value contained in passive RFID tags. Fig. 3 shows the area shaped by the electromagnetic wave from the RFID reader, which is defined as the reader recognition area.If RFID tags exist within the reader recognition area, the RFID tags are activated and can send the ID nd coordinatevalue to the RFID reader. Note that only the existence of RFID tags within the reader recognition area is checked in the RFID system—the distance measurement between the RFID reader and the tags is not available. The uncertainty about the

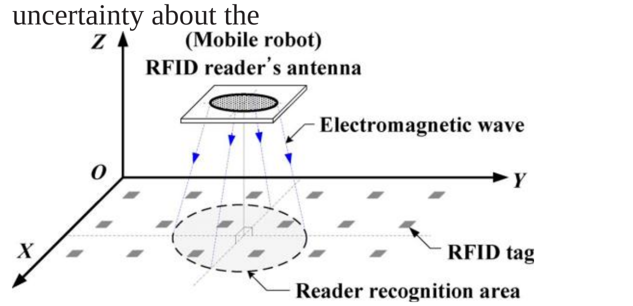

Fig3Shape of electromagnetic wave from RFID reader and recognition area over Zig-Bee.

.

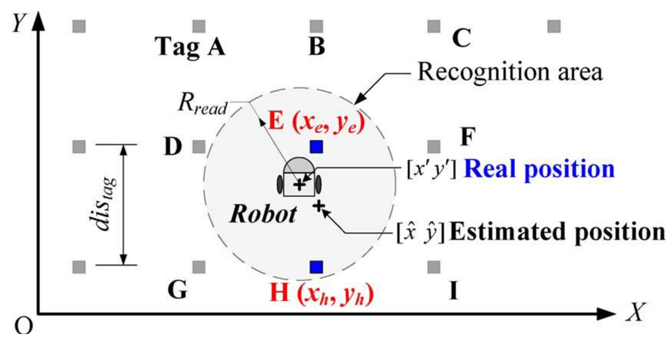

Fig.4Uncertainty about position estimation error caused by the reader recognition area

position estimation error caused by the reader recognition area is represented in Fig. 4. The estimation error is generated by the difference between the actual and the estimated mobile robot position. The position of the mobile robot can be obtained by the RFID tags that are located within the reader recognition area. If same RFID tags are active in spite of the movement of the mobile robot, the estimation position value is not changed. Thus, the tag-floor-based RFID system gives us constrained position data. That is, the mobile robot is considered to be located in the neighborhood of a particular location. Uncertainties about the position measurements can be modeled through the state space and observer function theory

IV. LEC

A. Uncertainty of Ultrasonic Sensor of RFID System over Zig-Bee.

All Rights Reserved © 2012 IJARECE

The process of recognizing the geometric local area near the mobile robot using ultrasonic sensors is defined as LEC.

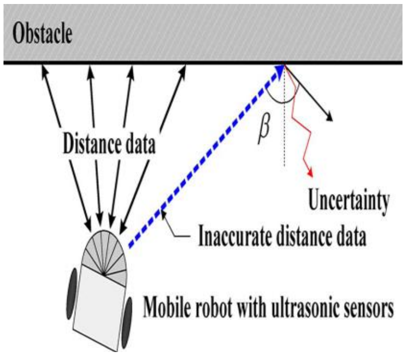

Fig5.Principle and uncertainty of ultrasonic sensor in LEC process

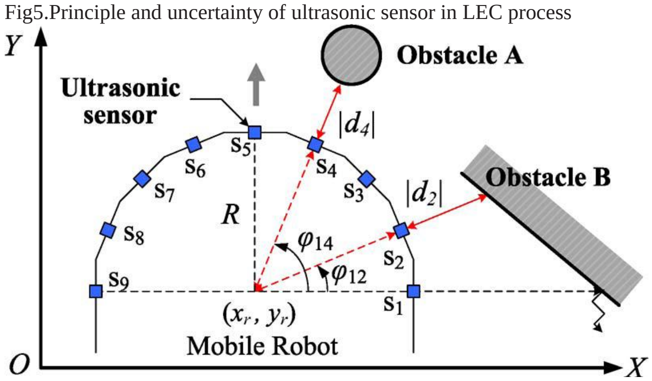

Fig6. Platform modeling such as the number and position of sensors in the Robot

Ultrasonic sensors installed in the mobile robot can measure the distance between the mobile robot and the obstacles.However, if the incidence angle or reflection angle β of the sonic beam is large, then accurate distance data cannot be obtained, as shown in Fig. 6. This follows from the exactitude of direction, sensitivity of the reflection angle, and sensitivity of distortion. Also, the radiation angle of the ultrasonic beam is larger when there is more distance between the mobile robot and the obstacle. Therefore, there are uncertainties when using ultrasonic sensors to recognize the local area near the mobile robot. We propose a scheme to reduce these uncertainties in the LEC process.

V. Fusion Algorithm

We estimate the position of the mobile robot through the matching of the aforementioned two data sets. The global position of the mobile robot as obtained from the RFID system is always estimated without reference to any obstacles;however, an estimated error is included as dictated by inherent uncertainties. On the contrary, the local environment map—which includes the local area of the mobile robot—is partially determined by obstacle distributions. The spread of the obstacles in the real driving environment of the mobile robot is not irregular in spite of the well-structured space. The global position of the mobile robot is considered for basis coordinates because the global position is estimated regardless of the obstacle. Uncertainties in global positioning are then reduced using the local map and data obtained from the mobile robot pertaining to the obstacles. The mobile robot moves continuously, and the flow of the fusion algorithm is depicted using step-by-step instructions.

Step 1. GPE: The observer function of the RFID system is obtained by (2), and then, the global position is estimated in Section III. The uncertainty, (i.e., the estimation error),is included in the estimated global position. The global position can be represented like (8).

Step 2. Mapping of the local environment: When the mobile robot moves within a given global position, a continuous local map is obtained by the movement of the mobile robot. The search area of the ultrasonic sensor is continuously expanded by the movement of the mobile robot. In mapping, the uncertainty is reduced by the matching of the straight and circular obstacles, i.e., (28) and (33), as shown in Section IV.

Step 3. Local position estimation: The local position $PL(k)$and displacement of the mobile robot are obtained by using the continuous local environment map.

Step 4. Global position compensation: If the GPE does not change in Step 1, we can use the local displacement of the mobile robot for the estimated global position. Because the moving distance and orientation of the mobile robot in an uncertain area of global position are obtained,the technical limitation of the RFID system stated in Section I is solved. In a given global position, the estimation error of the global position is reduced using the local displacement.

Step 5. Final position estimation: Comparing the compensated global position $P_G(k)$ from Step 4 and the local position from Step 3, the correspondence of two positions is decided. The set $v(k)$ is defined with the difference between two values of position, and the covariance matrix s for the difference is represented as follows:

$$v(k) = [\hat{P}_G(k) - \hat{P}_G(k)]$$
$$S(k) = E[v(k)v^T(k)]$$
$$v(k)S^{-1}(k)v^T(k) < e^2$$

All Rights Reserved © 2012 IJARECE

e is defined as the standard of correspondence and adjusted for the effective corresponding position value from the two position values. Until the difference between two values of position is satisfied, the standard Steps 4 and 5 are repeated Processing for continuous localization is repeated from Steps 1 to 5.

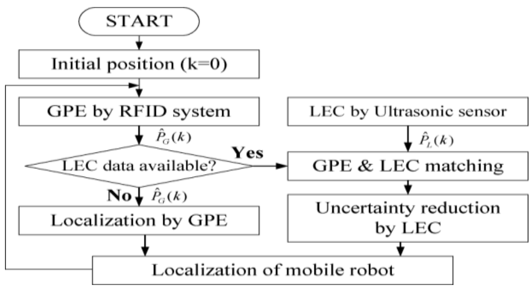

Fig7. Flow of the localization of the mobile robot from GPE and LEC.

TABLE 1
system parameter for experiments

Symbol	Quantity	Parameter
Dis_{tag}	Gap between RFID tags	0.5m
N	Number of ultrasonic sensors	9
α	Each placement angle between two consecutive sensor	22.5
γ	Threshold value for incident point of view	60
R_{read}	Radius of RFID reader's recognition area	0.3m

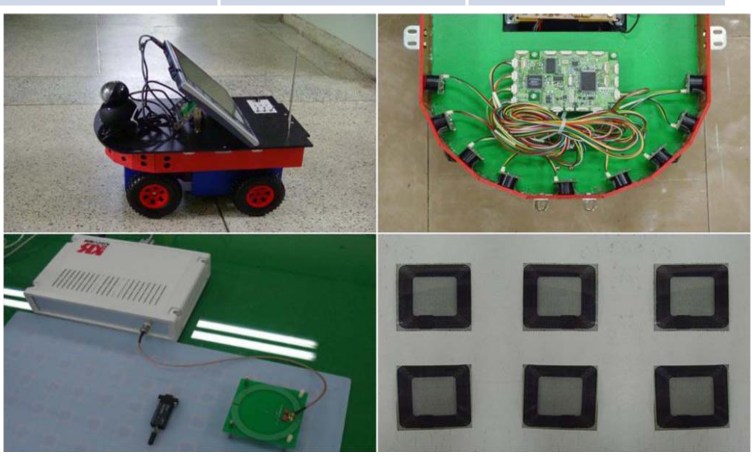

Fig. 8. Mobile robot systems for experiment: Mobile robot, ultrasonic sensor module in front of the mobile robot, RFID reader, and passive RFID tags.

VII. CONCLUSION

This paper has addressed an zig-bee-based localization scheme for mobile robots which uses ultrasonic sensors to compensate for deficiencies in previous RFID systems. First, two uncertainties of the basic RFID system were modeled. The global position of the mobile robot from the zig-bee system was obtained in the GPE process. Next, ultrasonic sensors were used for the LEC process. A method to separate straight and circular obstacles was proposed in order to reduce uncertainties in the LEC process. Using a matching algorithm for the global position and the local data, the estimation error and uncertainty were reduced. The proposed system was able to obtain the position of the mobile robot without any constraint from the environment.

REFERENCES

[1] M. Hadzic and E. Chang, "Application of digital ecosystem design methodology within the health domain,*IEEE Trans. Syst., Man, Cybern. A, Syst.,Humans*, vol. 40, no. 4, pp. 779–788, Jul.2010.

[2] M. L. Brodie, "Data integration at scale: From relational data integration to information ecosystems," in *Proc. IEEE Int. Conf. Adv. Inf. Netw. Appl.*,2010, pp. 2–3.

[3] J. P. Carmo, P. M. Mendes, C. Couto, and J. H. Correia, "A 2.4-GHz MOS short-range wireless-sensor- network interface for automotive applications,"*IEEETrans. Ind. Electron.*, vol. 57, no. 5, pp. 1764–1771,May 2010.

[4] K. A. Agha, M.-H. Bertin, T. Dang, A. Guitton, P. Minet, T. Val, and J.-B. Viollet, "Which wireless technology for industrial wireless sensor networks?The developmentof OCARI technology,"*IEEE Trans.Ind.Electron.*,vol. 56, no. 10, pp. 4266– 4278, Oct. 2009.

[5] H.-S. Ahn and K. H. Ko, "Simple pedestrian localization algorithms based on distributed wireless sensor networks," *EEE Trans. Ind. Electron.*,vol.56,no.10,pp. 4296–4302, Oct. 2009.

[6] V. C. Gungor and G. P. Hancke, "Industrial wireless sensor networks: Challenges, design principles, and technical approaches," *IEEE Trans.Ind. Electron.*, vol. 56, no. 10, pp. 4258–4265, Oct. 2009.

[7] B. Lu and V. C. Gungor, "Online and remote motor energy monitoring and fault diagnostics using wireless sensor networks," *IEEE Trans. Ind.Electron.*, vol. 56, no. 11, pp. 4651–4659, Nov. 2009.

All Rights Reserved © 2012 IJARECE

[8] C. Mitsantisuk, S. Katsura, and K. Ohishi, "Force control of human–robot nteraction using twin direct-drive motor system based on modal space design," *IEEE Trans. Ind. Electron.*, vol. 57,no. 4, pp. 1383–1392,Apr. 2010.

[9] N. Bu, M. Okamoto, and T. Tsuji, "A hybrid motion classification approach for EMG-based human– robot interfaces using bayesian and neural networks," *IEEE Trans. Robot.*, vol. 25, no. 3, pp. 502– 511, Jun. 2009.

[10] J. Borenstein and L. Feng, "Gyrodometry: A method for combining data from gyros, and odometry in mobile robots," in *Proc. IEEE Int. Conf.Robot. Autom.*, 1996, pp. 423–428.

[11] G. Antonelli, S. Chiaverini, and G. Fusco, "A calibration method for odometry of mobile robots based on the least-squarestechnique:Theoryandexperimentalvalidation," *IEEE Trans. Robot.*, vol. 21, no. 5, pp. 994–1004, Oct. 2005.

[12] J. M. Lee, K. Son, M. C. Lee, J. W. Choi, S. H. Han, and M. H. Lee,"Localization of a mobile robot using the image of a moving object,"*IEEE Trans. Ind. Electron.*, vol. 50, no. 3, pp. 612–619, Jun. 2003.

All Rights Reserved © 2012 IJARECE