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An Indoor Localization Scheme by Integrating Wiimote with an IR-LED Array for Mobile Robot Navigations

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Keywords: Wiimote, IR LED, Positioning, Mobile Robots, Collision avoidance, Navigations

ABSTRACT

Indoor localization of mobile units is critical for subsequent task development of intelligent living technology. Wiimotes have been demonstrated as an effective localization medium and certain localization schemes have been developed. However, due to lack of ability in identifying individual characteristics of IRLEDs, the past schemes fail to report the correct position information if the wiimote passes a shielding zone. In this work, a novel wiimote localization scheme is proposed to overcome the above-mentioned concern. The scheme is based on kinematics and coordinates transformation for locating the absolute displacement and this avoid the possible signal drifting during motion. Meanwhile, a controllable IR-LED array is designed to provide a convenient way for determining the specific zone in a virtually undistinguishable living space. With this feature, it is possible to interpret the absolute coordinate and orientation of mobile carriers even if they pass through possible shielding zones. The scheme is verified by using a 2-axis servomotor and a self-designed IR LED array with regular moving patterns. Finally, the scheme is applied on an omni-wheel mobile robot for demonstrating its applicability in trajectory control, obstacle avoidance for multi-robot path planning, and sensor fusions. The results indicated that the proposed scheme should be helpful in localization of moving objects in indoor living space applications.

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INTRODUCTION

Modern intelligent living relies on the assistance of indoor mobile units. Before one can perform specific functional design or motion planning, certain requirements of those mobile platforms must be satisfied. For example, successful trajectory control of these indoor mobile robots are essential for serving as the basis for subsequent task planning such as medical care or movement assistance tasks (Fox *et. al*, 1999; Glas *et. al*, 2015). An accurate and reliable motion sensing system is vital in developing trajectory controls and planning. Although there are many existed methods, such as inertial navigation system (INS) (Cho *et. al*, 2012), ultrasonic localization (Kim and Kim, 2013), laser range finders (Cifuentes *et. al*, 2014), and radio signals such as ultra-wide band signal (UWB) (Gezici and Poor, 2009) and received signal strength indication (RSSI) (Cheng *et. al*, 2011) methods, due to practical restrictions in different aspects, a flawless positioning technique has not yet been achieved. For example, image processing limited update rate for image sensing, drifting in INS, wall reflection for ultrasound, multi-path problem for radio signal based localization, the relatively coarse spatial resolution of using Zigbee (Watthanawisuth *et. al*, 2014) or RFID (Yang *et. al*, 2013), and possible unaffordable cost for multi-sensor fusion (Kim and Joo, 2015).

IR localization is another possible choice based on image sensing and this technique has been extensively used in smart items (Aitenbichler and Muhlhauser, 2007) or mobile robot localization. Recently, IR-LED based wiimotes have been used for many other applications beyond its original video game application (Lee, 2008), wiimote utilizes hardware circuit for reducing the IR image into a light spot and the response rate is therefore much faster. It therefore can be has used as an alternative candidate for indoor localization transducer with mili-meter sensing resolution (Chen *et. al,* 2010). It is possible to integrate wiimote with related indoor applications.

The wiimote sensing zone is based on the pixel location of the IRLED in the viewing area, which contains about one million pixels. The actual pixel length is proportional to the distance between the wiimote and the corresponding IRLEDs (i.e., sensing distance thereafter). A larger sensing distance can cover a larger area for sensing but the spatial resolution becomes poor, and vice versa. Such a trade-off between sensing zone and the spatial resolution implies that it is usually requires an array-like deployment in IRLED to cover the entire living space. For a typical sensing distance of 2.5 m, the spatial resolution is approximately 2 mm and the viewing area is approximately 80 x 105 cm. The resolution is sufficient but the area is too small to cover an entire living space. Previously, Chen et. al (Chen *et. al,* 2010) has proposed a multi-zone scheme to extend the sensing area of wiimote to virtually filling an entire indoor space by using a periodically deployed IRLED array. However, Chen's scheme is only valid under a pure translational motion. Gu et al further extended Chen's work to cover this main drawback by simultaneously monitoring the position of two IR-LEDs (Gu and Chen, 2015) and the scheme has been served as the feedback sensor to demonstrate its effectiveness in mobile robot controls.

Although Gu's work (Gu and Chen, 2015) has proved the applicability of wiimote as an effective position sensor for indoor environment, it cannot meet the most general scenario. That is, an initial position must be pre-known and the object must be seen continuously by the wiimote. Once it is out of sight and reappeared, the new initial position could not be automatically obtained. The reason is that its position sensed is actually the relative position at a particular zone and the new position is obtained by adding the displacement to the previous position. Consequently, once a carrier passes under a shelter such that the wiimote temporally loses the tracking, the accumulation process cannot be proceeded. Once the carrier leaves the shelter and is re-contacted by the wiimote, the reported position becomes erroneous. This flaw presents a remained obstacle for realizing the wiimote-based indoor localization. In this work, as schematically shown in Fig. 1, we proposed a novel scheme by integrating wiimote with a controllable IR-LED array for resolving the above problems.

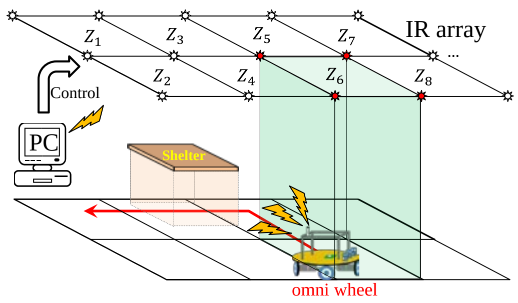

Fig. 1. Schematics for showing the scenario of the proposed wiimote localization system.

As mentioned earlier, it is not possible to distinguish individual IRLED by wiimote itself. Additional effort must be done. In this work, with a controlled input to the IR-LED array, it is possible to interpret the absolute coordinate as well as the orientation of mobile carriers. The scheme is robust even the carrier continuously moves in and out of a shelter. The preliminary concept was firstly addressed by us in the conference proceeding (Fu and Chen, 2014). In this article, detail development and explanation of the scheme and more simulation /experimental results, as well as demonstrations in indoor robot applications, are provided for further elucidate the concept and demonstrate the latest results. In addition, certain weakness and possible sensor fusion to overcome the drawback is also experimentally demonstrated.

BACKGROUNDS

As shown in Fig. 2a, wiimote contains a built-in "wiimote camera" to detect up to four IR LEDs with visual angles of approximately 42◦(X) and 33 ◦ (Y) to form a sensing zone with a resolution of 1024×768 pixels. There have been many investigations on exploring wiimote's applications beyond its original design, particular in multi-media (Lee, 2008). In this work, the localization-related ability of wiimote and its potential as an indoor global position/ orientation sensor is the major concern. For a fixed sensing distance, a lateral relative motion between wiimote and IRLEDs can be detected and the position of IRLEDs can then be determined. Our previous investigation (Chen *et. al,* 2010) indicated that the resolution is around 2 mm for typical indoor space and the bandwidth was 107 Hz. In most situations, the observed maximum deviation is limited by the pixel resolution. As shown in Fig. 2b, the resolution linearly depends on the sensing distance. For example, for a sensing distance of 1.6 m, the resolution (mainly due to pixel size) is 1.2 mm. Both sensing resolution and dynamic bandwidth imply that wiimote could play as a fast and accurate position sensor in a living space.

However, as addressed in Section I, there are two practical concerns for using wiimote in indoor localizations. First, the detectable motion range is in the order of 1-2 m, which cannot cover the entire living space. Specifically, with a sensing distance of 3 m, the sensing area would be 1.24 and 0.95 meters. Second, the individual IR LED cannot be distinguished and it cannot detect self-rotation using a single IR LED. Both concerns demand that special effort be made in order to use wiimotes for tracking indoor mobile units. To address the first concern, a multi-zone localization scheme is developed (Chen *et. al*, 2010). For the second issue, a scheme based on simultaneously interpreting the positions of two IR LEDs, followed by coordinate transformation, was proposed for extracting the rotating motion of an object in our previous work (Gu and Chen, 2015). The scheme worked well with high accuracy and has been successfully applied in mobile robot trajectory control. However, the position of the object is obtained by accumulating the displacement at each time increment. If the object cannot be seen through the entire journey, significant localization errors could occur.

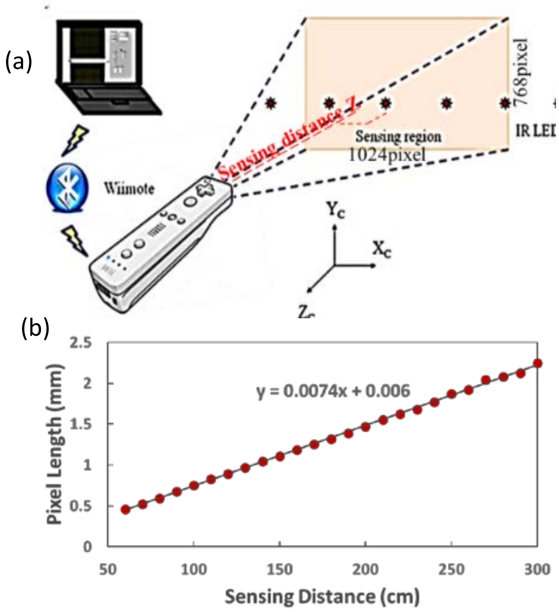

Fig. 2. (a) Schematics of wiimote location sensing and (b) the tested pixel resolution as a function of sensing distance.

Through the efforts of our previous works, the position and orientation of mobile robots in a large indoor open area can be successfully monitored. However, the influence of possible shelters (such as moving in and out under a table) on localization performance remains unsolved. This issue must be well addressed for satisfying the general requirement in indoor movement, where eye of sight is frequently blocked. A modified scheme addressed in Section III is proposed to solve the concern. By the scheme proposed, the positioning of mobile units in a large indoor space containing IR shelters such as furniture could be achieved. Furthermore, with the fusion of other sensors demonstrated in Section V, it is possible to localize the mobile unit even beyond the eye of sight of wiimote.

WIIMOTE LOCALIZATION SCHEME

Consider an indoor space with an IR LED array on the ceiling where the coordinates of all IR-LEDs are pre-determined by other means, the wiimote-mounted mobile robot moves in a 2D manner. The deployment of IRLEDs must be pre-calculated such that there are no extra IRLEDs can be seen during maneuver. At the very beginning, the IR-LEDs in the array are sequentially turned on and off to make interaction with the wiimote mounted on the robot. In most situation, the wiimote cannot detect the turned-on IRLEDs unless the robot is right on the specific zone. Once the contact is established (i.e., IRLEDs seen by the wiimote), the zone where the robot is located is known based on the control program and the absolute position of the zone center has been identified. The remaining work is to find the location of the robot at this zone relative to the zone center by using the information of the true coordinates and the wiimote readouts of these observed IR-LEDS by developing a coordinate transformation. By such a transformation, both the robot location and the orientation can be found. Fig. 3a shows the schematic working flow for the scheme. Basically, this scheme aims to solve three major issues. First, it must be able to locate the initial position of a robot in a periodically deployed IRLED array. As mentioned earlier, the array-like deployment is necessary for covering the entire indoor living space. However, this also causes the difficulty for identifying the initial location without extra effort. Second, the current position within the specific zone must be deduced from the observed IRLED pixel frames. One key issue is to avoid position drifting due to the accumulation of error after long operation. Finally, the scheme must demonstrate the ability to re-capture the correct location once a robot reappears from a shielding zone or entered from an unobservable location.

The entire working flowchart of the scheme is shown in Fig. 3b. First, as mentioned above, these periodically deployed IR LEDs are turned on/off in a controllable manner and the wiimote mounted on the mobile robot is then to detect the LED signals.

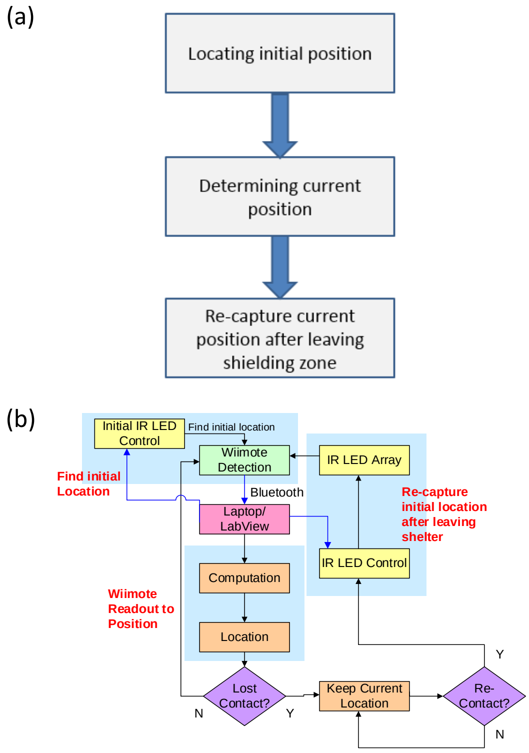

Fig. 3. (a) Schematic functional diagram of the proposed wiimote localization scheme and (b) the functional flowchart of the entire localization scheme

By this manner, the specific zone can be determined. Once the zone is determined, the next issue is to determine the position of a reference point Rc inside the zone and followed by works to determine the robot orientation and distance with respect to Rc. Finally, if robot enters a shielding zone, the IR LEDs will continuously turn on/off to locate the robot till the robot re-appears.

The global location of Rc can be calculated based on the pixel coordinate of the observed IRLEDs. However, the seen IRLED patterns are not unique. As shown in Fig. 4, there are three possible types of multiple IR LED pattern seen by the wiimote. Based on the number of IR-LEDs contacted, the manner to find Rc is slightly deferent. For example, if four IR-LEDs are observed, the reference point Rc is determined as the geometric center of the four LEDs. On the other hand, if only two IRLEDs are detected, the Rc is determined as the average location of these two IRLEDs. Notice that if only one IRLED is seen, the result is inconclusive and the wiimote-carried robot will continuously hoover around until multiple IRLEDs has been seen. Once Rc has been determined, the remaining issue is to calculate the distance and orientation of the wiimote (or the mobile robot) relative to Rc. Based on the information and the coordinate of Rc, the global position of the mobile robot can be found.

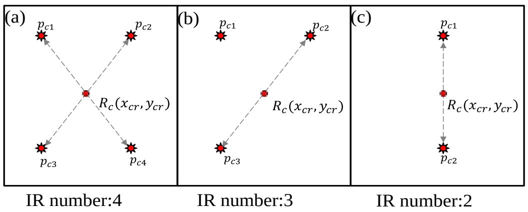

Figure 4. Three possible patterns of IR-LEDs observed by wiimote and the definition of the associated reference point Rc.

Taking the situation shown in Fig. 5(a) as the example, the relationship between the reference point Rc and the locations of two key-IR-LEDs pc1 and pc4 is

$$\begin{bmatrix} x_{cr} \\ y_{cr} \end{bmatrix} = \frac{1}{2}\begin{bmatrix} x_{c1} + x_{c4} \\ y_{c1} + y_{c4} \end{bmatrix}. \qquad (1)$$

From the true coordinates and the wiimote readouts (i.e., pixel coordinate) of pc1, pc4, and Rc, it is possible to calculate two rotating angles θ and ϕ for robot orientation. Here θ is the rotation angle between the global and local coordinates (or the amount of rotation of the robot) and ϕ the relative rotation with respect to the local coordinate. That is, by referring to Fig. 5(a), it can be seen that

$$\theta = \tan^{-1}\frac{(x_{c1} - x_{c2})}{(y_{c1} - y_{c2})} \qquad (2)$$

$$\emptyset = \tan^{-1}\frac{(y_{cr})}{(x_{cr})}. \qquad (3)$$

Finally, schematically shown in Fig. 5(b), the rotation of robot can be found. Meanwhile, the relative distance between the mobile robot and Rc can be found from the wiimote readout. Denoting the distance as $\overline{R_G C_G}$ shown in Fig. 5(b) and combining the orientation of wiimote (or the robot) relative to Rc, the global coordinate of the mobile robot can be found as

$$\begin{bmatrix} X_{Gc} \\ Y_{Gc} \end{bmatrix} = \begin{bmatrix} X_{Gr} \\ Y_{Gr} \end{bmatrix} - \overline{R_G C_G}\begin{bmatrix} \cos(\emptyset + \theta) \\ \sin(\emptyset + \theta) \end{bmatrix} \qquad (4)$$

Once this information can be determined, the robot location and orientation at the entire living space can be found by adding the relative distance with the absolute coordinate of Rc. Notice that the above calculation assumes that the wiimote is mounted on the center of rotation. If the requirement is not meet, additional coordinate transform must be added to count the translation of wiimote position due to rotation.

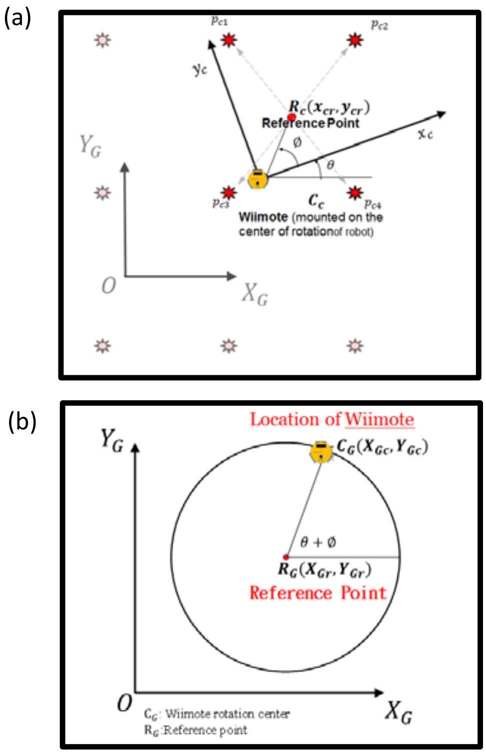

Fig. 5. Schematic plots for finding the (a) orientation and (b) distance from the reference point of a mobile robot.

If the mobile robot enters a shelter, the wiimote cannot see any IR LEDs. Under such a circumstance, the IR LED array will enter a mode to switch on/off the LEDs in a controllable manner to search the robot till this robot leaves the shelter and the IR LEDs are re-captured by the wiimote. Because the computer knows the positon of the captured LEDs with the aid of LED controller, the procedure to re-calculate Rc and the distance and orientation of the robot can be re-initiated automatically in an absolute (or global) coordinate manner in real time. This avoids the possible error for our previous method using incremental approach.

The computational flow of the proposed method schematically shown in Fig. 3(b) can be briefly stated below and is programmed in a NI Labview environment.

1. Carefully layout an IR-LED array and pre-recording the coordinates of all IR-LEDs to form a database. The IR-LEDs are controlled to turn on/off sequentially to scan the entire living space. Once the wiimote detects IR-LEDs, the zone where the robot located is immediately determined.
2. Using the coordinates and the wiimote readout (i.e., pixel coordinates) of these contacted IR-LEDs to determine the coordinate of the reference point Rc by using the relation such as Eq.(1). Notice that if only one IRLED is detected, the program will ask the robot to hover around until multiple IRLEDs are seen.
3. Calculate the rotation angle θ and the angle ϕ using Rc and the wiimote readout of the contacted IR-LEDs (i.e., Eqs.(2) and (3))
4. Compute the absolute position and orientation of the robot by adding the information of zone and the relative position inside this zone w.r.t. Rc (i.e., Eq.(4)).
5. For next time increment, if robot enters a shelter, executing step 1 till the robot re-appear. Otherwise, the execution flow returns to step 2 and repeat the process (step 2-4) until the motion stops.

Here, it is worth to compare the proposed scheme and the previous published approach (Gu and Chen, 2015) for illustrating the improvement. Previously, the IR-LEDs are not controlled and it is required to pre-determine the starting location of the robot. It then uses the pixel coordinates of the sensed IR-LEDs to determine the rotation angle and perform coordinate transformation to calculate the position increment of the robot for the next time step. The new position is obtained by adding the increment to the previous location. If the robot can be monitored continuously, the scheme works perfectly.

Conversely, the current approach uses the known IR-LEDs position to find the reference point and the robot rotation. The robot location and orientations are then obtained. For each time increment, the robot location is re-calculated in an absolute coordinate sense and is therefore not relied on the previous robot location. This rules out the possibility of error accumulation. For continuous monitoring, this method works as find as the previous report scheme. However, when a robot moves into a shelter and is eventually moves out of the shelter and re-contacted by wiimote, its location must be reported correctly. This concern can be fully covered by the proposed approach. However, in the previous work (Gu and Chen, 2015), the determination of this position relies on the previous step's information, which cannot be defined if a robot moves out of a shelter and thus its calculation would result in an incorrect answer. This characteristic implies that the proposed scheme could be suitable for more general indoor living space where many shelters resulted from furniture is expected and mobile robots will be out of sighted frequently.

EXPERIMENTAL RESULTS

An Arduino micro control unit (Uno MEGA 2560) is utilized to serve as the bridge between the host computer and the IR LED array. As shown in Fig. 6a. With a LabView environment, the computer is responsible to receive the signal from wiimote via Bluetooth and sending command to the Arduino card via USB for operating the IR LED array in a planned manner. Fig. 6b schematically shows the scanning sequence of the IRLEDs for covering the entire living space. A circuitry of the IRLED array control is responsible to turn on/off specific IRLED unit with transistors after receiving the command. Currently, the switching rate is 10 Hz, which is sufficient for our applications. In the future, with a better coding, the switching rate should be able to be further enhanced.

For convenient, a 3×5 IR LED array is then constructed for validating the proposed scheme. As shown in Fig. 7a, a wiimote is mounted on a two-axis linear servomotor for a controllable movement and an accurate position for comparison. A shelter is placed between the wiimote and the IR-LED array (shown in Fig. 7b) to mimic the scenario of robot moving through a table with a rectangular path (refer to Fig. 7c). The localization accuracy is approximately ± 0.7mm (with a sensing distance of approximately 0.9m). Both the entire moving path and the moving histories of each displacement component are presented for providing a more detail illustration.

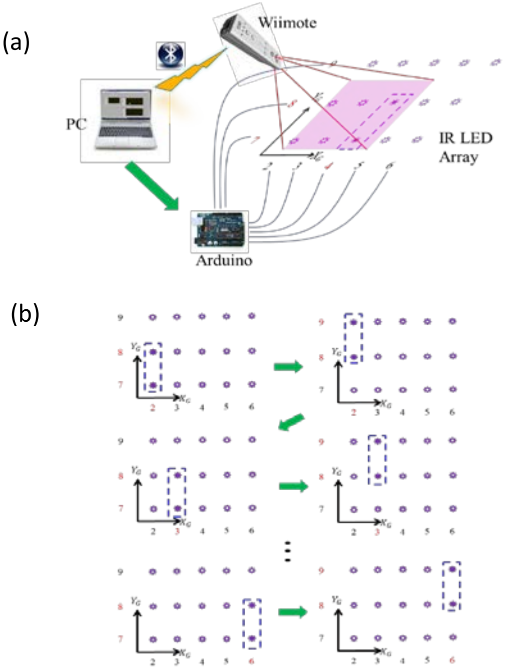

Fig. 6. (a) The functional plot of the controllable IR LED array, (b) the schematic plot for indicating the scanning of IR LEDs for covering the entire living space.

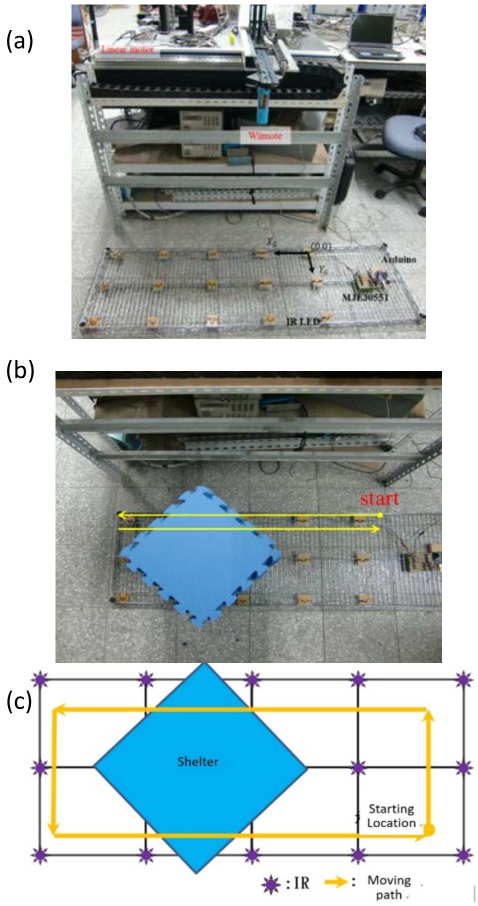

Fig. 7. Wiimote moves passing under a shelter. (a) the overall system layout, (b) the shelter, and (c) the schematic plot to illustrate the moving path.

The experimental results are shown in Fig. 8. It can be seen that before entering the shielding area, the robot position can be monitored by wiimote quite well. When the robot is in the shielding area, naturally it is temporally losing contact and no position information can be reported. However, once the robot travels out of the shielding zone, the wiimote immediately re-captures the position and orientation of the robot. Although this result may be easy to be achieved by other type sensors (which suffer from other problems in their applications), it is not trivial for wiimote localization in multi-zone wiimote localization. For example, also shown in Fig. 8, by using the previous scheme, one can see that the previous scheme work perfectly until the robot enters the shielding zone. However, once the robot leaves the zone and reappeared, the previous scheme can no longer recover its position. This comparison shows the key feature of the proposed method in this work. As mentioned in Section I, with the problem being solved, one should be able to use wiimote localization in general indoor living space.

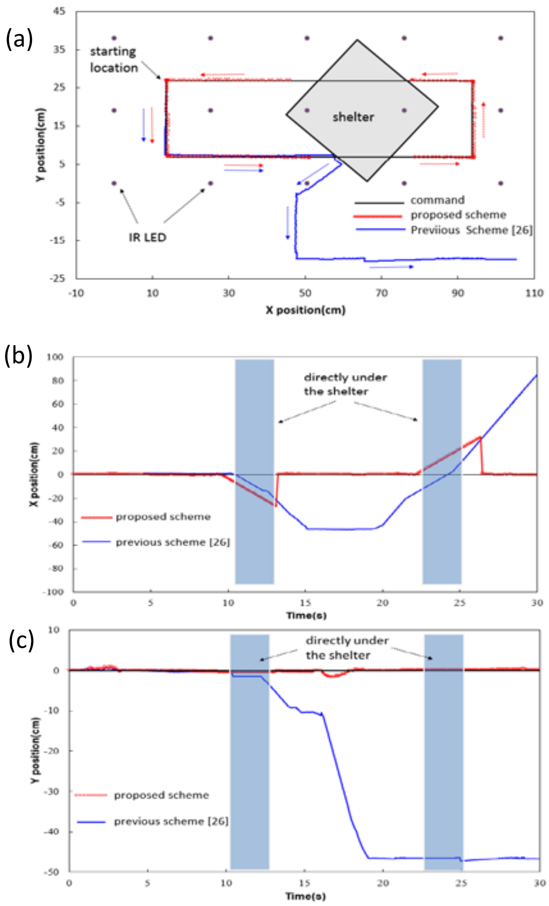

Fig. 8. The experimental results for comparing the performance of the proposed and the previous localization schemes. (a) moving history and errors in (b) horizontal (i.e., x) and (c) vertical (i.e., y) directions

DEMONSTRATIONS

After validation, the scheme is then integrated with an omni-wheel mobile robot to demonstrate its ability on monitoring and controlling indoor robot. As shown in Fig. 9a, the self-designed mobile robot has a main body consisting of three motors (IG42) and three sets of omni-directional wheels. Together with a BS2 control card, servo control unit (Parallax, PSC), driver (Parallax HB25), communication board (EB500), and on board batteries, as well as a wiimote, the mobile robot can move at a maximum speed of 1m/s. On the other hand, the indoor environments, as well as the human-machine graphical interface, are also established under a LabView programming environment for commanding and monitoring the movement. Please refer to Fig. 9b and 9c for illustration. Meanwhile, a 3×5 IRLED array is deployed (with a separation of 60 cm × 80 cm) on the celling with a sensing distance of 2.18m also shown in Fig. 9a. Under such a sensing distance, the localization accuracy is estimated to be ±1.7mm based on the calibration results shown in Fig. 2. The entire area for localization is therefore estimated as 4 m x 1.5 m based on the deployment.

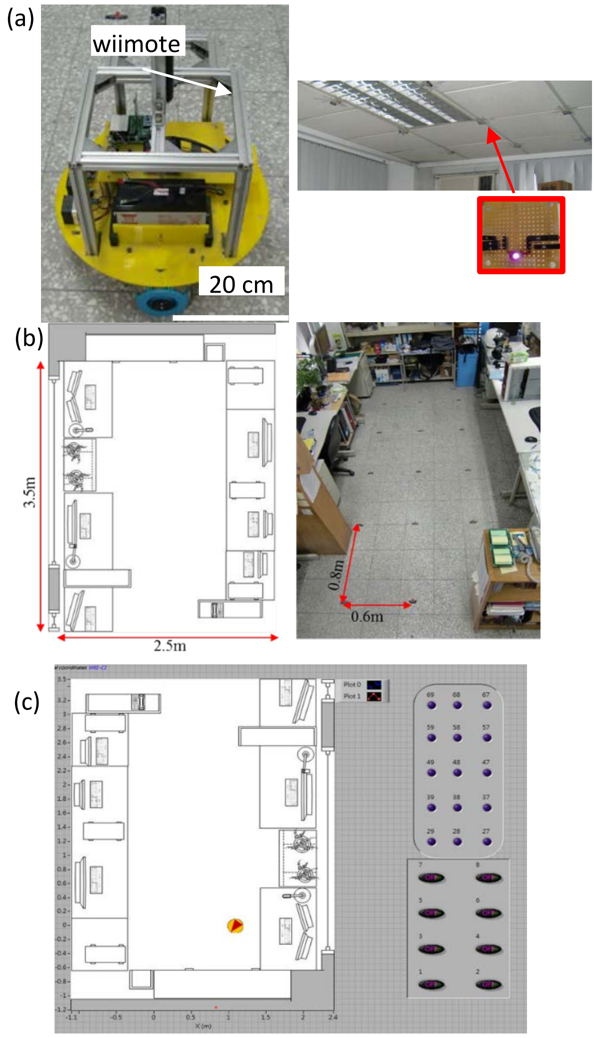

Fig. 9. Setup of indoor localization: (a) the mobile robot and the IRLEDs deployed on the celling, (b) the indoor map, and (c) the user interface

The first experiment is to examine the ability of the proposed scheme in robot path control. The robot is forced to move a rectangular path under a shelter with a simple PID controller for following a desired path. As shown in Fig. 10, it can be seen that the wiimote system can successfully monitor the trajectory of the robot before it enters the shielding zone and quickly re-contacts the robot once it leaves the shelter. However, two interesting issues can also be observed from Fig. 10.

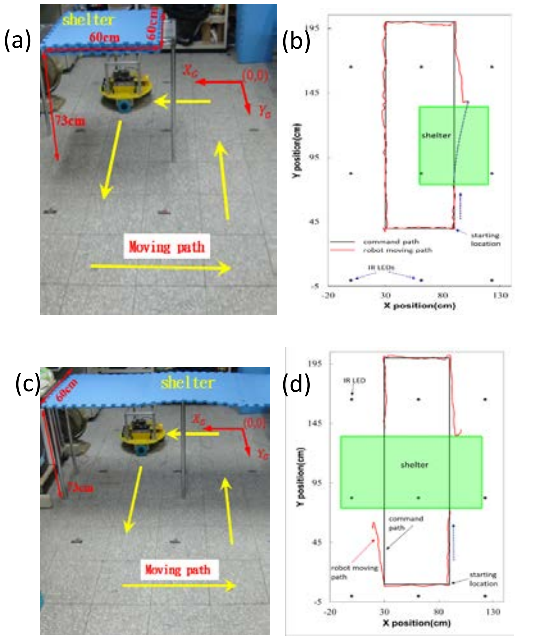

Fig. 10. Experimental results to show the robot travel through (a) a single shelter and (b) its results and (c) a double shelter and (d) its results.

First, due to the eye of sight effect schematically shown in Fig. 11a, the robot cannot be seen before it leaves the shadow projected by the shelter. As the result shown in Fig. 10, the robot position cannot be seen immediately after leaving the shielded region. Second, without the monitoring of wiimote, the robot can only move in an open loop manner in the shielded zone. Due to wheel slipping, both the desired position and orientation deviate from the designated values considerably when the robot re-appears. Once the wiimote is re-contacted with the IR LED array, the localization scheme immediately provides corrected coordinate and thus triggering the feedback control to fix the position and orientation errors. Fig. 11b schematically addresses this issue. In Fig. 10d, the robot path exhibits a more severe adjustment and this reveals the effort of correcting position tracking error by feedback control. The steady state deviation is about ± 1 cm. The purpose of this experiment is to demonstrate the feasibility of integrating the proposed scheme in indoor robot trajectory control and the result is promising.

Furthermore, by incorporating with obstacle avoidance algorithm for multi-robot path planning using the potential method (Pratomo *et al.*, 2010) with a Lennard-Jones potential (Lennard-Jones, 1924), the mobile robot also demonstrates the capability in trajectory modification. The experimental setup and results for static obstacle avoidance is shown in Fig. 12.

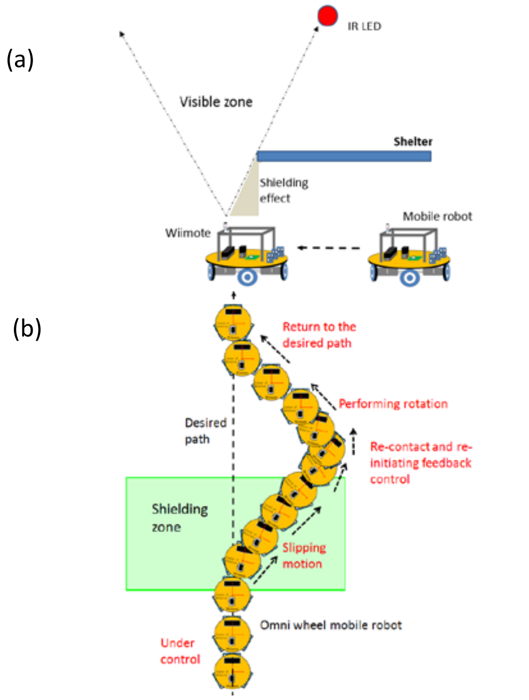

Fig. 11. Schematics for illustrating (a) the shielding and (b) the deviation of the mobile robot under the shelter due to lose of position feedback

The coordinates of the static obstacles are pre-determined and stored in computer. It can be seen that the trajectory following capability depends on moving speed. Nevertheless, the maximum deviation of the experimental results and the desired path based on potential theory is still within 3 cm, which is mainly due to the maneuverability of the self-designed mobile robot and is not limited by the localization errors. Meanwhile, the setup and results for dynamic obstacle avoidance are also presented in Fig. 13, where the position of the dynamic obstacle is monitored by a wiimote mounted on the celling. Based on the positions of robot and the obstacles reported by the wiimote systems, the host computer computes the desired path based on potential method for achieving the obstacle avoidance motion tasks successfully. In summary, these experimental results provide a promising demonstration to show the feasibility of using the proposed scheme in obstacle avoidance for multiple-robot path planning.

It is also worth to demonstrate a feature of guiding the movement of robot by simply controlling the on/off of IR LED. That is, we turn on an IR LED and it guides the robot move toward its location based on the detected wiimote signal. Here the robot traces the wiimote and it is possible to force the robot to move in a desirable manner. The result is shown in Fig. 14. It can be seen that the robot can move under a preplanned manner essentially. However, due to possible wheel slipping, the actual moving path deviates from the desired straight movement slightly.

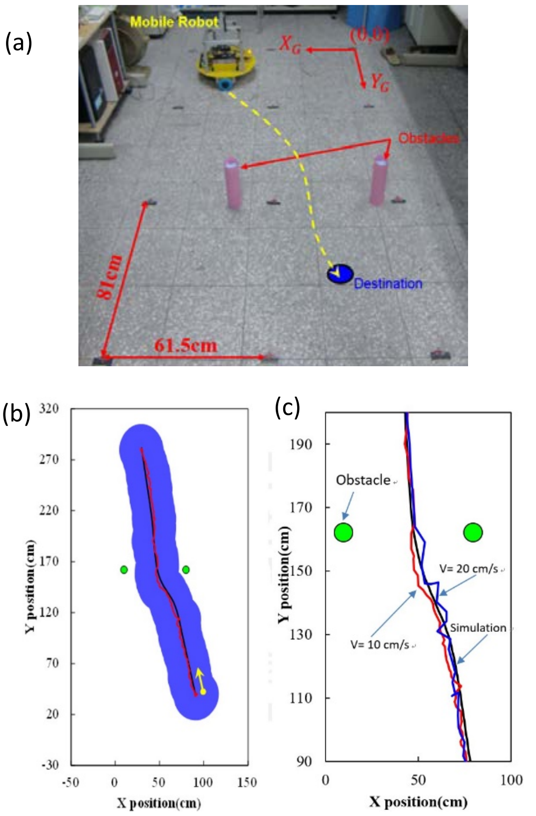

Fig. 12. The static obstacle avoidance experiment. (a) system setup, (b)results with robot moving speed = 10 cm/s, and (c) enlarged view with speeds of 10cm/s and 20 cm/s.

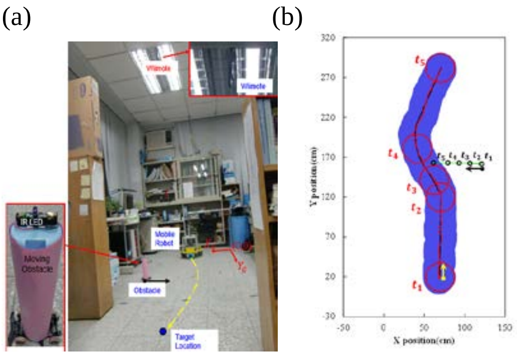

Fig. 13. The obstacle avoidance experimental results (a) system setup and (b) experimental results (t_1=0, t_2=10s, t_3=20s, t_4=30s, t_5=40s). The blue region represents the entire robot movement area.

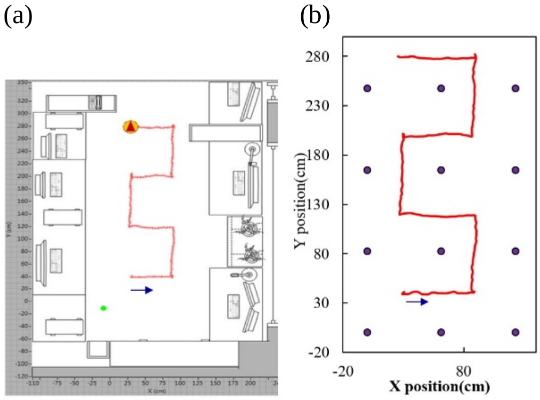

Fig. 14. Experimental results on mobile robot guidance: (a) indoor map for illustrating the robot motion and (b) moving data with IRLED positions indicated in dots.

Finally, a concept by integrating IRLED control in an entire living space with robot task planning is briefly proposed here. The concept is illustrated in Fig. 15. It is possible to use proper IRLED controls to partition the living space into several classes for scheduling (or constraining the service space) the tasks of indoor service (for example, cleaning) robots. By controlling the IRLED array mounted on the celling of a space, the attributes of the space changes. For example, if all IRLEDs are switched off, it may represent an area not allowed to be entered for service robots.

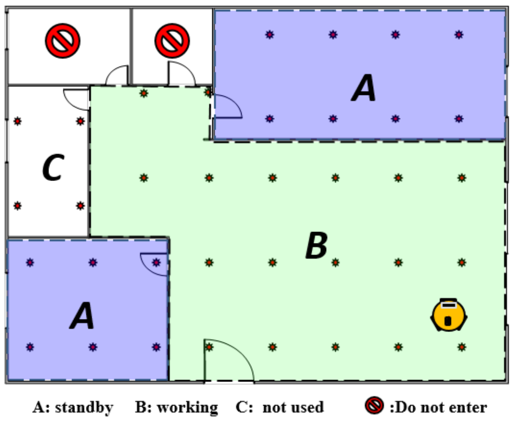

Fig. 15. A concept of using IRLED control for scheduling the living space for indoor robot task planning.

DISCUSSION

Wiimotes have demonstrated their feasibility in indoor localization. However, due to their inherent limitations, the past developed scheme can only be used provided that the robot can be seen through the entire journey. Once the robot moves across a shielding zone, the past scheme breaks down. In this work, a modified 2D multi-zone localization scheme based on wiimote is proposed for solving this potential important concern and thus providing a localization scheme for handling a more general indoor environment and both translation and rotation motions can be accurately monitored and the location of carriers can be determined. Thus the scheme provides a reliable global position sensing for monitoring indoor moving robots and the position control over the entire living space can also be achieved. Thus, we believe that the proposed novel scheme could significantly enhance the applicability of wiimote-based indoor localization applications in the future. Furthermore, the problem can also be understood as a mapping from the sensor image plane to the ceiling plane, which is basic homography consisting of pure translation and rotation. It is possible to re-investigating the problem by adopting methods from computer vision (Hartley and Zisserman, 2003) for gaining robustness against possible uncertainties such as misplacement of the ceiling markers.

This work also demonstrates the possibility of guiding the movement of mobile robots by controlling the on/off of IR LED arrays. Based on this result, it is possible to utilize IR LED to make virtual compartments of mobile robots. That is, by designing specific lighting sequence or pattern, specific robots may or may not be permitted to enter certain areas and this could possibly represent a new concept of indoor living space planning.

SUMMARY AND CONCLUSION

In this work, a novel wiimote localization scheme is proposed and validated to solve the above-mentioned concern. By working with a controllable IR-LED array, it can detect the absolute position and orientation where the robot is located. The scheme is experimentally verified by using a servomotor-driven wiimote with a controllable IRLED array. Finally, the scheme is applied on an omni-wheel mobile robot for mimicking the trajectory control and obstacle avoidance in a complicate indoor living space and for exploring other new indoor task managements to demonstrate the possible advantages of this localization scheme in indoor living space applications.

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結合 Wiimote 與紅外光 LED 陣列之室內定位系統與其在機器人路徑規劃之應用

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為提升室內機器人於室內環境運作的可靠度，需依賴高精度之室內定位技術，本論文發展一改良型 Wiimote 2D 室內定位技術，結合可控式 IR 陣列於 Wiimote 室內定位系統，建立一室內的絕對座標系統作為本定位系統的定位演算法之依據，以擴展機器人在室內移動的運用性。除此之外，本文也發展一套機器人路徑規劃演算法，運用位能場的特性使機器人能夠於動態及靜態的環境中完成自主規畫路徑。最後整合全向移動載具發展人機介面，提升使用者與機器人之間的互動效果，改善機器人操作時的便利性，達到智慧服務生活之目的。本文所發展的定位系統定位精度可維持在公分等級，透過該定位系統之高定位精度特性，配合路徑規劃使得載具成功執行所希望的任務移位，有效提升使用者在操作機器人時的可控性與可觀性。