On the Use of Smart Wearable Technology for Gynecology and Obstetrics Care

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Abstract. This paper applies Smart Wearable Technology (SWT) to Gynecology and Obstetrics Care, to protect new born babies from being stolen. We designed a wearable infant bracelet based on Bluetooth Low Energy (BLE) technology which can monitor posture of baby, and built BLE Gateway (BLEG) network to collect broadcast data from the former; at the same time, we developed Infant Management Software System (IMSS) for indoor positioning and events classification. We also designed three experiments: Experiment A is to build RSSI-Distance Model of infant bracelet and the results show that the RSSI will attenuate with distance increasing within ten meters; Experiment B is to test the reliability of BLEG and the results show that two BLEGs cooperation can reduce the missing rate compared with only one BLEG; Experiment C is to evaluate three BLEG Threshold Configure Methods (BTCM) including Static, Half-Dynamic and Dynamic used in indoor positioning and the results show that Dynamic is the best method of three Methods by miss rate of 3.66%. The product of this paper has been applied to the fourth hospital of Shijiazhuang City.

Keywords: Wearable Technology · Bluetooth Low Energy · Infant bracelet BLE Gateway · Infant Management Software System · RSSI-Distance Model BLEG Threshold Configure Method

1 Introduction

Since October 2015, China has implemented a comprehensive two-child policy. The number of newborns has increased year by year, and the phenomenon of adding extra beds in maternity hospitals has become even more serious which brings much confusing to gynecology and obstetrics. Moreover, most of hospitals are lack of objective management methods other than security guard. As a result, the baby's safety cannot be guaranteed.

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Automatic Identification System (AIS) such as Bar codes and Radio Frequency Identification (RFID) are applied to logistics [1], transportation [2], medical [3], access control [4]. According to the survey, wearing double RFID tags still has a probability of 3% cannot be identified, wearing only one RFID tag just has correct recognition rate of 78% [5, 6]. In addition, RFID signal is of direction and easy to be blocked [7]. Taking these into account, Apple Inc. proposed a new technology called iBeacon [8] based on Bluetooth Low Energy [9] in 2013, which is widely used in indoor positioning [10, 11] and Identification. Smart phones are frequently carried by peoples, and there is a lot of research on the use of mobile phone APP for health monitoring [12, 13]. Bluetooth is an effective way to send data from wearable device to smartphone compared to RFID. In this work, we want to develop a product based on SWT and BLE for Gynecology and Obstetrics Care which should include wearable infant bracelet, monitoring network, algorithm, safety design, software. In addition, we also need to verify this product through experiments.

2 Methods

2.1 Infant Bracelet Design

The hardware of infant bracelet is made up of three main modules, it reads data from three-axis accelerometer module to collect the baby's moving signal, and uses the master module to measure the battery voltage and potential difference between two wrist strap contacts, then broadcasts data together out via the BLE module. The accelerometer adopts the MC3410 manufactured by the mCube which communicates with the master module via the IIC. The master module uses the nRF51822 manufactured by Nordic Semiconductor with a BLE module included. The hardware structure of infant bracelet shows in Fig. 1.

As shown in Fig. 2, the components of infant bracelet consist of PCBA, battery, shell and conductive wrist strap. The button battery CR1620 of standard voltage of 3 V, is assembled on one PCBA side; The conductive wrist strap can be adjusted to

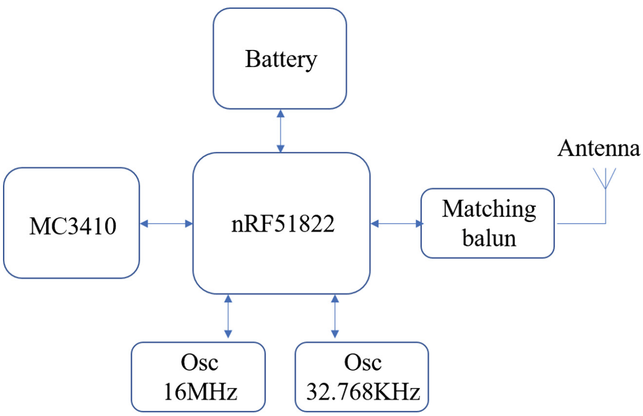

Fig. 1. Hardware structure diagram

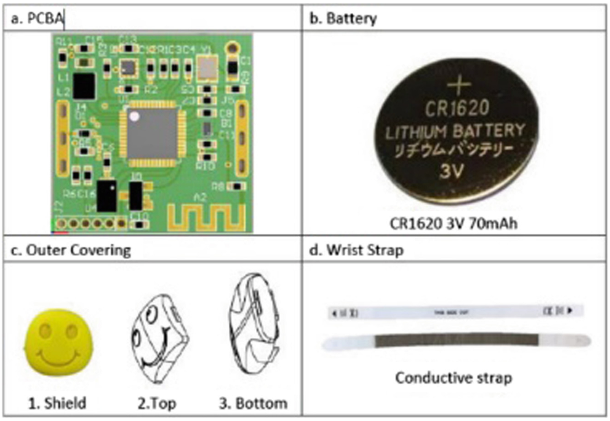

Fig. 2. Components of infant braceletHeadings.

match the baby wrist, and its conductive characteristics is designed to contact PCBA as a circuit to prevent malicious removal.

2.2 BLEG Network

The BLEG used in this study is xbeacon_cloud produced by Lan-ke-Xun-Tong Technology Inc. as shown in Fig. 3, which is powered by POE. It transmits the collected data broadcasted from infant bracelet to the server through Ethernet with TCP/IP protocol. The system network is shown in Fig. 4.

Fig. 3. xbeacon_cloud

2.3 Algorithm Design

Indoor Positioning Algorithm. In this study, an algorithm based on RSSI is proposed. The algorithm is divided into three steps: (1) Ten-Point Window Processing, remove the maximum and minimum value of RSSI in ten points before the current point, then calculate the average RSSI value of remaining eight points as the current point value; (2) Threshold Comparison, position the bracelet in the BLEG coverage area if the current time RSSI value is greater than the BLEG Threshold; (3) Intersection BLEG RSSI Comparison, the infant bracelet's signal may be monitored by multiple BLEGs, in this case, the location of the BLEG of greater RSSI will be current position unless the bracelet is detected by a senior BLEG arranged at the exit.

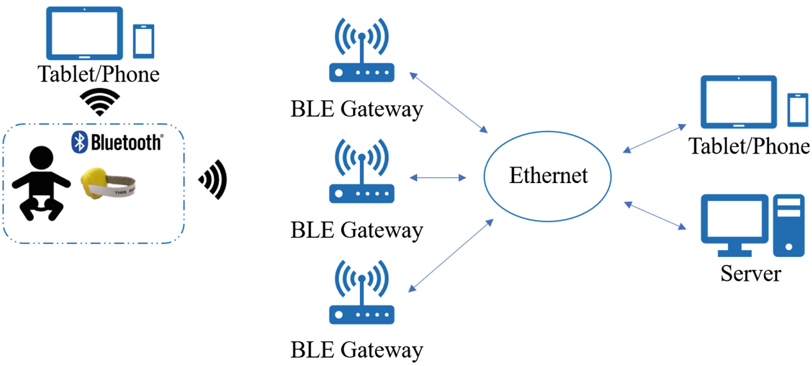

Fig. 4. System network

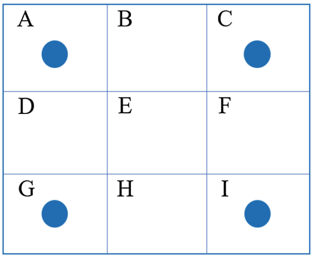

Fig. 5. 3 * 3 range

BTCM. This study uses Dynamic BTCM for each BLEG. In the case of Fig. 5, the space is divided into 3 * 3 range, BLEG is arranged at position E, and the reference transmitter (infant bracelet label) is arranged in the region A, C, G and I. Threshold of BLEG is updated with the minimum RSSI value of four reference transmitters every hour.

2.4 Safety Design

BLEG Filter. There are many other BLE devices in the actual field, which increase the pressure of the BLEG and affect the system performance. Therefore, this study adds a filter function in the BLEG to distinguish infant bracelet from other devices by Bluetooth name.

BLEG Layout of Dangerous Area. The dangerous area is set as the boundary of the monitoring range. This study requires accurate and timely detection of infants through this area. In order to reduce the detection miss rate, two complementary BLEGs are arranged.

BLEG Grade. In this study, BLEG is divided into three grades: Safety BLEG is arranged in ward and corridor, which has the most number and monitors infant gesture, position and bracelet status; Nurse Station BLEG is used for pairing infant bracelet and baby data; Dangerous Area BLEG of the highest grade is to monitor whether there are babies cross its coverage.

Events Classification. This study classifies events which may occur on bracelet and baby into five: Crossing Dangerous Area (CDA), Wrist Strap Cut (WSC), Bracelet Undetected (BU), Low Power (LP), Moving Posture (MP). The responses of the different events including Dangerous Area Alarm (DAA), Nurse Station Alarm (NSA), Nurse Station APP Notification (NSAN) and Nurse/Mom APP Notification (N/MAN) are shown in Table 1.

Table 1. Events response classification

Events	Notification platform			
	DAA	NSA	NSAN	N/MAN
CDA	✓	✓	✓	✓
WSC		✓	✓	✓
BC		✓	✓	✓
LP			✓	✓
MP			✓	✓

2.5 Software Design

This study designed IMSS such as Nurses Station Management System (NSMS) on Windows platform and Nurse/Mom APP on Android platform, as shown in Fig. 6. NSMS software has features including baby status monitoring, go out application, bracelet pairing, BLEG setting, event history and so on. Nurse APP can monitor all baby's statuses. Mother can use APP to look after their babies.

Infant Bracelet Pairing. In this research an innovation pairing method is proposed as can be seen in Fig. 7: type baby's information in NSMS; wake up bracelet by using conductive wrist strap to connect it; click on the pairing button on the software interface and shake the bracelet; write MAC of bracelet into database and complete pairing.

Windows APP of Nurse Station Nurse APP Mom APP

Fig. 6. APP of multi platforms

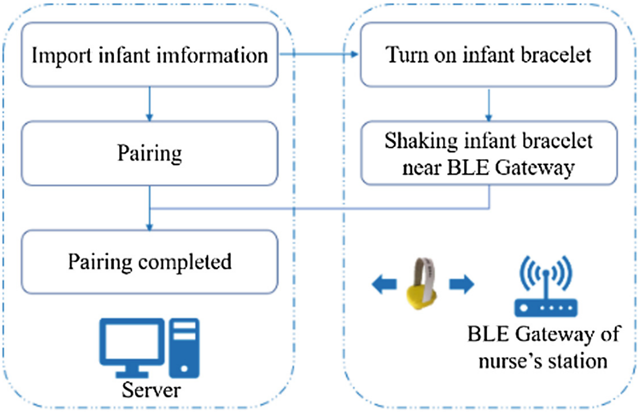

Fig. 7. Bracelet pairing flow diagram

Nurse/Mom Phone Registering. This study uses UUID read by Nurse/Mom APP to distinguish between different mobile devices. Type the work id of nurse or the case id of mother into their APP to register (see Fig. 8).

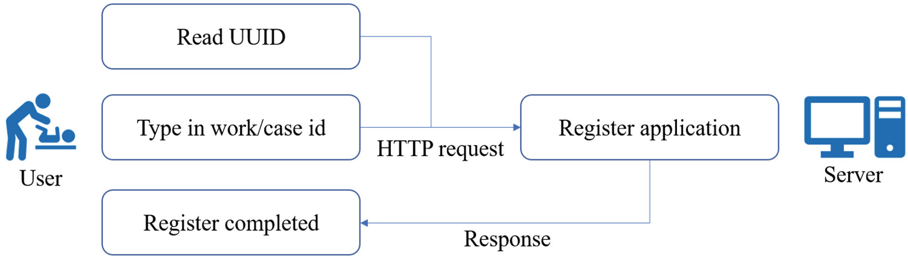

Fig. 8. Flow diagram of phone registering

3 Experiments

3.1 RSSI-Distance Model

Experiment Description. The purpose of this experiment is to establish a RSSI-Distance Model of infant bracelet using an indoor square of twenty meters long and ten meters wide for the test field. A BLEG is placed in the square center with eighty centimeters height position. The fifteen infant bracelets are placed two, five, eight and ten meters away from the BLEG with 100 RSSI data recorded each time. At last, we calculates the mean value of RSSI to establish the RSSI-Distance Model.

Results. Results show that RSSI value is linearly related to distance between infant bracelet and BLEG in the range of ten meters (see Table 2), and the signal is too weak for more than ten meters.

Table 2. RSSI-distance model

Distance	RSSI
<2	>−88
2–5	−93–−88
5–8	−95–−93
8–10	−110–−95
>10	Very wake

3.2 BLEG Reliability Test

Experiment Description. This test is conducted to test the reliability of the BLEG in the dangerous area by changing the number of infant bracelets (one, five, ten and thirteen) and the speed of crossing the region (walk, jog and sprint). The average speed of walk is about 0.99 m/s, jog about 2.61 m/s, sprint about 4.97 m/s. Test area is a corridor of twenty meters long and 2.5 meters wide, as shown in Fig. 9. BLEGs are arranged in the middle of the corridor on both sides with a radius of five meters range. The tester carries infant bracelets through the corridor from the left side to the right side ten times under the same condition and records the miss rate by Eq. 1.

$$Miss\ Rate = \frac{\text{Undetected Bracelets}}{\text{The Number of Bracelets}} \tag{1}$$

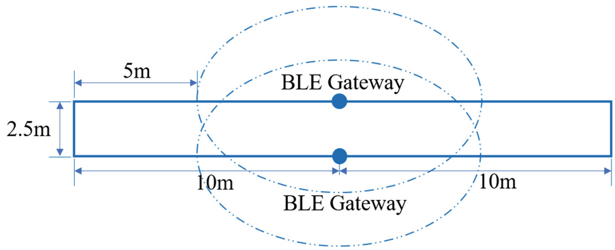

Fig. 9. Testing area

Results. The test results of single and two BLEG under different test pressures are shown in Table 3. Increasing in the number of bracelets and the speed will make the miss rate rise, and the cooperation of two BLEGs can reduce the miss rate.

3.3 BTCM Evaluating

Experiment Description. The purpose of this experiment is to analyze the effect of different BTCM on positioning accuracy. BTCM are divided into Static, Half-Dynamic and Dynamic. The Static uses the minimum RSSI value of the bracelet as the threshold for the first time; The Dynamic takes the minimum RSSI value of four reference

Table 3. Miss rate (%) of detecting

BLEG	Bracelet numbers	Crossing speed		
		Walk	Jog	Sprint
BLEG A	1	0	0	20
	5	0	2	4
	10	0	2	9
	13	0	1.53	14.61
BLEG B	1	0	0	0
	5	0	0	6
	10	0	1	13
	13	0.77	1.53	18.46
BLEG A&B	1	0	0	0
	5	0	0	0
	10	0	0	3.03
	13	0	0	4.61

bracelets as a threshold every hour; The Half-Dynamic updates the threshold with the mean of the previous day's Dynamic threshold. Position area is a square of seven meters long side with wall thickness of fifteen centimeters, as shown in Fig. 10 A–I. Reference bracelets are place at A, C, G and I. The BLEG is placed at position E. The eleven test infant bracelet are placed in the A–D, F–L area. Three minutes of data is recorded each time.

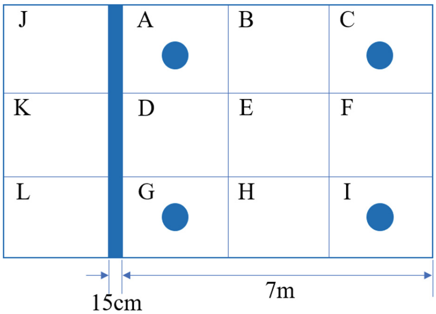

Fig. 10. Position area

Results. The positioning error rate calculated by Eq. 2 corresponding to the three BTCMs is shown in Table 4. The average error rate of Static is 5.19%; The Half-Dynamic is 3.92%; The Dynamic is 3.77%. The results show that the Dynamic method can improve the positioning accuracy.

Table 4. Error rate (%) of position

Area	Threshold config methods		
	Static	Half-dynamic	Dynamic
A	0	0	0
B	4.75	4.75	2.97
C	0.24	0.24	0.24
D	0.74	0.98	0.49
F	6.52	4.83	5.56
G	10.86	8.84	5.56
H	6.37	4.66	5.15
I	20.2	11.22	14.46
J	0	0	0
K	0	0	0
L	5.82	6.58	5.82
Average	5.04	3.82	3.66

$$Error\ Rate = \frac{\text{The Number of Error Positioning Bracelets}}{\text{The Number of Bracelets}} \tag{2}$$

4 Conclusion

In this study, we have designed an infant bracelet device, established monitoring network and developed IMSS.

Furthermore, We have designed three experiments to verify our system: First, we designed RSSI-Distance Model experiment to verify the relationship between RSSI and distance, and results showed that the RSSI will attenuate with distance increasing within ten meters; Second, we designed BLEG Reliability Test with pressure of different number of infant bracelets and speed of crossing, and results showed that the cooperation of two BLEGs can reduce the miss rate of 4.61% compared with 14.61% and 18.46% of only one BLEG; Last, we designed an experiment to evaluate three BTCMs, and results showed that the average error rate of Static is 5.04%, the Half-Dynamic is 3.82%, and the Dynamic is 3.66% which is the best.

The product of this paper has been applied to the fourth hospital in Shijiazhuang City.

The shortcomings of this study are as follows: (1) The accuracy of positioning algorithm should to be improved due to indoor positioning is easily impacted by environment. but this is limited by the bottleneck of Bluetooth technology. (2) This study only takes into account CDA, WSC, BU, LP, and MP five events, but the actual case will be more complex.

References

1. Yan, Q.: Research on fresh produce food cold chain logistics tracking system based on RFID. Adv. J. Food Sci. Technol. **7**(3), 191–194 (2015)
2. Al-Lawati, A., Al-Jahdhami, S., Al-Belushi, A., et al.: RFID-based system for school children transportation safety enhancement. In: GCC Conference and Exhibition, pp. 1–6. IEEE (2015)
3. Li, X., Yao, D., Pan, X., et al.: Activity recognition for medical teamwork based on passive RFID. In: IEEE International Conference on RFID. IEEE (2016)
4. Woo-Garcia, R.M., Lomeli-Dorantes, U.H., López-Huerta, F., et al.: Design and implementation of a system access control by RFID. In: Engineering Summit, II Cumbre Internacional De Las Ingenierias, pp. 1–4. IEEE (2016)
5. Lo, N.W., Weh, K.H.: Anonymous coexistence proofs for RFID tags. J. Inf. Sci. Eng. **26**(4), 1213–1230 (2010)
6. Jarvis, M., Tarlow, B.: Wi-Fi position fix. European Patent Application EP 2 574 954 A1, March 2013
7. Stamatescu, G., Sgarciu, V.: Evaluation of wireless sensor network monitoring for indoor spaces. In: 2012 International Symposium on Instrumentation and Measurement, Sensor Network and Automation (IMSNA), vol. 1, pp. 107–111 (2012)
8. Newman, N.: Apple iBeacon technology briefing. J. Direct Data Digit. Mark. Pract. **15**(3), 222–225 (2014)
9. Bluetooth SIG Core Specification v4.1 (2013)
10. Fard, H.K., Chen, Y., Son, K.K.: Indoor positioning of mobile devices with agile iBeacon deployment. In: Electrical and Computer Engineering, pp. 275–279. IEEE (2015)
11. Rida, M.E., Liu, F., Jadi, Y., et al.: Indoor location position based on bluetooth signal strength. In: International Conference on Information Science and Control Engineering, pp. 769–773. IEEE (2015)
12. Higgins, J.P.: Smartphone applications for patients' health and fitness. Am. J. Med. **129**(1), 11–19 (2016)
13. Wang, J., Wang, Y., Wei, C., et al.: Smartphone interventions for long-term health management of chronic diseases: an integrative review. Telemed. J. E Health **20**(6), 570–583 (2014)