The Performance of Human Detection System with One-way Communication

Kodai Yokoo†, Hiroshi Yasukawa†and Akitoshi Itai‡

†Graduate School of Aichi Prefectural University, 1522-3 Ibaragabasama, Nagakute-shi, Aichi Japan
im112007@cis.aichi-pu.ac.jp, yasukawa@ist.aichi-pu.ac.jp
‡College of Engineering, Chubu University, 1200 Matsumoto-cho, Kasugai-Shi, Aichi Japan
itai@cs.chubu.ac.jp

ABSTRACT

A human detection system based on pressure sensors has been investigated as a part of an inexpensive sensor network system [1][2]. This paper presents the performance of the system represented by transmission characteristics and human walking path tracking.

Keywords: Sensor network, One-way communication system, Human detection, Ubiquitous network

1 Human detection system with one-way communication network

Human detection system is composed of multiple sensor nodes and one receiver. The sensor nodes consist of a wireless transmitting function, a weight sensor, and a micro controller [3], and are placed to cover an observing floor. It is expected to reduce a power consumption and a hardware cost by employing one-way communication, since the receiving function is not included in sensor nodes.

Sensor nodes transmit sensing data when they are stepped by a human who walks on an observation area. The sensing result is represented as a binary bit. 1 (0) indicates that an amount of pressure is greater (less) than threshold. We can estimate human movement by analyzing received data. A synchronization and a retransmit control are not performed due to a lack of a receiving function. The reliability of one-way communication is improved by transmitting packets composed of present and past data.

2 Receiving delay for pressure data

The receiving delay should be demonstrated to discuss an effectiveness of human detection system. The main reason of delay is the resending of collision data. The receiving delay shown here indicates the time elapsing from pressure data generation to receiving.

2.1 Theoretical formula

Assume that sensor nodes, which were stepped on, transmit a packet including N_a previous data at an interval of r seconds. r indicates the average value of exponential distribution. In this case, sensor nodes operate and transmit a packet N_a+1 times during an average of $(N_a+1)\cdot r$ seconds to improve reliability. The expectation of the number of pressure detection over $(N_a+1)\cdot r$ seconds is expressed as P. The operating period O per unit time is given as:

$$O = 1 - e^{-\frac{r(N_a+1)}{r(N_a+1)/P}} = 1 - e^{-P}. \quad (1)$$

The traffic $G(N_a)$ is expressed by (2).

$$G(N_a) = O\frac{n(l_h + (1+N_a)l_d)}{cr} \quad (2)$$

where, r, l_h, c and l_d are defined by Table 1 The packet collision ratio $C(N_a)$ is represented by $1-e^{-2G(N_a)}$. Then we get the receiving ratio of the pressure data for one transmission of $1-(1-e^{-2G(N_a)})$. In one-way communication network, the packet receiving ratio for i time transmissions $R(i)$, where $(1 \le i \le N_a+1)$ and the one for N_a+1 times transmission are given by

Table 1: Transmission parameters

r	Average of transmitting interval	0.5 sec
l_h	Header size	112 bits
c	Transmission capacity	250 kbps
l_d	Data size	1 bit

$$R(i) = 1 - (1-e^{-2G(N_a)})^i \quad (3)$$

$$R(N_a+1) = 1 - (1-e^{-2G(N_a)})^{N_a+1}, \quad (4)$$

respectively. The receiving ratio for ith transmission period ($Q(i)$) takes the form

$$Q(i) = R(i) - R(i-1) = (1-(1-e^{-2G(N_a)})^i) - (1-(1-e^{-2G(N_a)})^{i-1}). \quad (5)$$

Here, the average of receiving delay for ith transmission is obtained by $r\cdot(i-1)$.

2.2 Evaluation

The receiving delay for pressure data is demonstrated here. The transmitting parameters for human detection system are shown in Table 1, where r is defined as footstep interval[4], c and l_h are obtained from ZigBee module. The l_d indicates pressure binary data.

Evaluation in the same packet loss ratio

In order to obtain the same collision ratio, packet loss ratio (PLR) is given by

$$\text{PLR} = (1-e^{-2G(N_a)})^{N_a+1}. \quad (6)$$

The theoretical receiving delay and the parameters are listed in Table 2. n in Table 2 is the maximum value which satisfies the packet loss ratio 10^{-5}. The maximization is performed by adjusting N_a.

From Table 2, even P increases 100 times, the difference of receiving delay is less than 0.13 seconds. In order to clear an occasion of few differences, the receiving ratio and the expected value of receiving delay for ith transmit is shown in Fig.1 and Fig.2, respectively. These figures indicate that the receiving ratio and the receiving delay is similar in the condition of different P. From (2), (3) , the receiving ratio and the receiving delay depends on traffic $G(N_a)$.

Table 2: The receiving delay under PLR=10^{-5}

P	n	N_a	Receiving delay (sec)
0.01	65910	89	3.66
0.10	6891	88	3.62
0.50	1666	86	3.53
1.00	1037	86	3.53

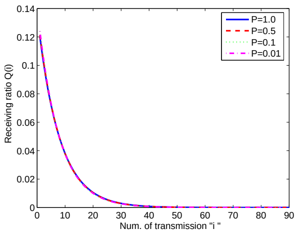

Figure 1: Receiving ratio $Q(i)$ for ith transmit

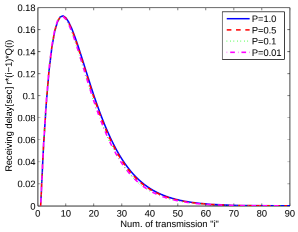

Figure 2: Expected value of receiving delay for ith transmit

From these results, the averaged receiving delay for human detection system is about 3.6 seconds in the condition of PLR= 10^{-5}. In addition, the averaged receiving delay depends on PLR and traffic.

3 Walking path estimation

In this paper, we assume that a human walks in an observation area that holds sensor nodes. The simulation conditions for walking path estimation are introduced here.

3.1 Observation area and sensor interval

The observation area is a square region with side length of L meters. The number of 85×85 sensors, which satisfy the packet error rate 10^{-5}[2], are placed at equal intervals. We assume that the sensor interval, ℓ, is defined as $L/85$.

3.2 Walking Model

In order to simulate human movement, walking parameters are needed. For convenience, a foot is taken to be a rectangle with foot breadth and foot length. The parameters are listed in Table 3. These parameters are defined from the dimensions of the average adult Japanese male[5].

4 Estimation of walking path

In the human detection system, to place many sensors is not reasonable as a sensor network system. This indicates that we need to estimate a walking path from few sensors. In this section, we present the walking path estimation and its accuracy.

4.1 Definition of error

The actual walking path is defined by the linear line which connected the position of human step sequentially. The error between actual walking paths and estimated paths is introduced here. Fig.3 explains the calculation of error for example. Fig.3 shows the pedestrian walks 6 steps during stepping two sensors. Line A and B represents estimated and actual walking path, respectively. The sum of triangle areas formed by these line is defined of S_1(Fig.3). We calculate S_2,S_3,$\cdots$,S_{M-1} using the location of next stepped sensor.

Table 3: Walking parameter

Length of stride	44[cm]	Step width	9[cm]
Length of foot	26[cm]	Foot breadth	10[cm]

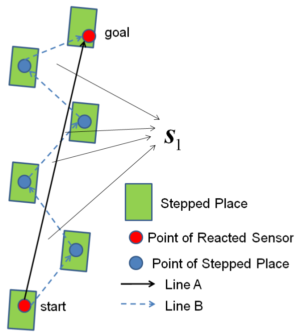

Figure 3: Example of S_1

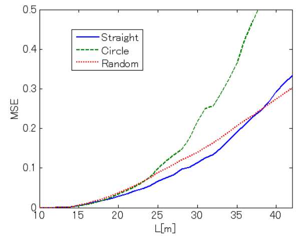

Figure 4: MSE vs. L for walking pattern

Assume that MSE is a difference of position when a human walks 1 meter. Then, we have

$$\mathrm{MSE} = \frac{1}{L_s} \cdot \frac{1}{n} \sum_{i=1}^{m-1} S_i \qquad (7)$$

where L_s is length of stride, n is the number of steps by pedestrian in observation area, and m is the number of stepped sensors. The point of stepped place is the center of foot.

4.2 Walking pattern

We present the influence of walking patterns and the observation area for MSE. Walking patterns are the straight, circle and random walking. In each walking pattern, we calculate MSE when L is increased from 10[m] to 42[m] by simulation. The radius of circle walking is defined as 5[m]. MSE vs. walking pattern and L is shown in Fig.4. The difference of MSE between walking patterns is increasing when L is greater than 22[m].

5 Conclusions

In this paper, the performances of human detection system with one-way communication are presented. In addition, we proposed an estimation method on walking path tracking and evaluated the estimation precision of walking path in human detection system with sensor operating ratio.

In the future tasks, it is required to implement the human detection system with a sensor network.

REFERENCES

[1] K.Inoue and N.Tokura, "A study on the One-way Communication in Sensor Networks", IEICE General Conference, B-7-109, 2007.(in Japanese.)

[2] K.Okita, A.Itai, Y.Sumi and H. Yasukawa, "Evaluation of Sensor Network Based on One-way Communication with Sensor Operating Ratio", IEICE Tech. Rep. Vol.110, No.130, pp.35-40, 2010.(in Japanese.)

[3] S.Sakata, "Sensor Network", Ohmsha, 2006.(in Japanese.)

[4] Y.Shoji, A.Itai and H.Yasukawa, "Personal Identification Using Footstep Detection in In-door Environment", IEICE Trans. Fund., Vol.E88-A, No.8, pp.2072–2077, 2005.

[5] M. Sato, "Dictionary of Japanese", Asakura, 2003.(in Japanese.)