Development of RFID Textile and Human Activity Detection Applications

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Abstract. We developed RFID woven textile and a customized textile inspection machine with an automatic map making function. These developments have potentials to extend location aware systems in real use. In this paper, we present a process of the development of RFID, the developed map-making system and an accuracy of the automatically made map and time saving effect. And we outlined two prototypes of human activity detection using RFID textile. One is a pilot application of a tracking system using 19-meter coated RFID textile as a carpet. A person's tracking is detected by shoes that RFID readers were embedded. Another one is a pilot application of a human-activity tracking system using RFID textile wear. By wearing it, the predefined behaviour is detected by embedded RFID readers in the environment. In section 6 conclusions and future works are discussed.

Keywords: RFID textile, Map making system, Human activity detection.

1 Introduction

Recent technological advancement makes the physical and digital worlds interlinked and makes people, computers and environment seamlessly integrated in part of our daily life. Thus human interface dealing with medium between people and computer systems called context-aware technology is becoming important research area. Many researches dealing with context-aware environments have concentrated on supporting people at work as well as at home. [1][2] One example of a promising technology for supporting interlinking physical and digital world is Radio Frequency Identification (RFID), which is an electronic tagging technology that allows the detection and tracking of tags, and consequently the objects they are affixed to. Conventional applications using RFID tags are frequently seen in the supply chain world for RFID

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attached object tracking.[3] The ability to do remote detection and tracking coupled with the low cost of passive tags has led to the widespread adoption of RFID in the field. On the other hand, massively distributed RFID tags are used to support the navigation of mobile devices, robot manipulation and tracking of a person.[4][5][6] .

These applications use RFID tags as position detection method by correlating physical coordinates with RF-IDs as a mapping table. By massively distributing RFID tags, each RFID tag acts as a position sensor in a way, which reacts depending on the position of a reader and responds to its unique ID. Though the method has high potential, the conventional method tends to need time and cost when to implement system into physical space. First of all, it is necessary to implement RFID tags. Secondly it is necessary to make a map integrating RFID tag ID and physical coordinates. Also conventional RFID based infrastructure is static so that once the RFID based environment is deployed, it is difficult to move. To solve these problems, authors developed RFID tag woven textile. Also authors developed a map-making system which automatically generates a map under the manufacturing process. RFID textile is flexible and light-weight position detection material which can be applied to RFID-carpet, curtain, cloth, chair or any other products using textile.

This paper is organized as follows. Related works are discussed in section 2. In section 3, we present the process of the development of RFID textile and in section 4 we present a developed map-making system and an accuracy of the automatically made map and time saving effect. In section 5, we outlined two prototypes of human activity detection using RFID textile. One is a pilot application of a tracking system using 19-meter coated RFID textile as a carpet. A person's tracking is detected by shoes that RFID readers were embedded. Another one is a pilot application of a human-activity tracking system using RFID textile wear. By wearing it, the predefined behaviour is detected by embedded RFID readers in the environment. In section 6 conclusions and future works are discussed.

2 Related Works

One of the authors developed RFID embedded outdoor space called PATIO.[4] 1,349 RFID active tags were embedded in the 1,700m^2 floor space for position detection. These tags were arranged 2D lattice with 1.2 meter spacing. By having developed PATIO, compelling issues arose for achieving the practical use of position detection using RFID technology. These were those of dealing with replacing batteries of the Active RFID tags, the cost of the installation and maintenance of the larger tag area. Besides, once the RFID tag environment was deployed, it is difficult to reconstruct or move it to another space.

By implementing RFID textile system, authors reduce implementing time and cost as well as increase flexibility of the system. In addition, RFID textile is applied as material of many products. Willis et al. introduced an architecture and design using passive RFID information grid for location and proximity sensing for the blind user.[6] They were positive about using passive RFID tag for location detection from the perspective of maintenance and cost. Even though they presented the possibility of implementation of RFID tags as information grid both indoor and outdoor areas, their approach was not brought to realization. So the feasibility test of location detection was performed in comparatively small area. Bohn et al. also presented a potential of super-distributed RFID tag infrastructure over large areas or object surfaces.[7]

Their main contribution of the paper was the advocate of distribution schemas such as the density and structure of tag distributions and tag typing and clustering. They demonstrated the feasibility and versatility of their research by making prototype of a location –aware autonomous vacuum cleaner in small area. At this moment, we made 1.0m x 19.0m RFID textile which was performed as location detection carpet and were positive about making larger areas. Vorwerk, a German company, manufactured carpets sewn RFID tags for the intelligent navigation of service robots.[8] They demonstrated a navigation of a cleaning robot. They were the first commercial company advocating the possibility of RFID location detection method down to earth. However, sewing RFID tags on the carpet was expensive comparing to weaving if it becomes mass production.

Also the RFID textile could be adapted to many products other than carpets. But the Vorwerk system was targeted only to the carpet's infrastructure. Though no applications adapting RFID textile is not known, many researches dealing with detection of human activity by deploying RFID technology were advocated. iGlove and iBracelet were wearable RFID system for detecting human activity. [9] These wearable system deployed RFID reader system into wearable product such as a glove or a bracelet.

The system inferred people's actions from their effect on the environment such as objects with which they interact. Sixthsense was a human activity detection system under enterprise environment.[2] The interaction of a person and an object was detected by tagging office supplies and a person. These two researches challenged to detect human-activity by tagging a person and an object. The goal of our system is to make wearable RFID tag system as a normal cloth and embed RFID reader system in the environment. This may realize more unobtrusive human activity sensing system as well as have redundancy of the detection system since there are multiple RFID tags covered in a body.

Though there were many discussions about the effectiveness of massively distributed RFID tags for location detection, there were few discussions about map make efficiency. To correlate physical coordinates with RF-IDs as a mapping table is important as a basis of the system. Bohn et al. presented a prototype system for collaborative map making using mobile vehicles. [7] Multiple mobile vehicles move around the tag space starting from a known position, each vehicle chooses a random path through the area and thereby keeps track of the tags encountered and the relative inter-tag distances. The separate tag observations are subsequently merged by means of an efficient least-square coordinate transformation algorithm. Our map make system is a customized textile inspection machine. So the map make procedure is very different from it. Our proposing system automatically correlates RF-ID and physical coordinates under the ordinal manufacturing process. Thus it is possible to save time for running the location aware system immediately at the site.

3 RFID Textile Development

The goal of this development of RFID textile is to make automatic RFID textile manufacturing system with no RFID damage while weaving as well as doing after-treatment such as dying and coating. If the goal is accomplished, RFID textile could become commercial production for interior or apparel material.

Fig. 1. Prototype shirt (left) and vinyl covered textile carpet (right)

First of all, we used commercial RFID tags for making the textile by manually interlacing tags with polyester thread. We made two prototype rolls of RFID textile by inserting rows of 6 horizontal 5.3cm(width) x 0.35cm (height) tags every 10cm pitch with the size of 120cm(width) x 150cm(height). And two 1.0m x 30.0m RFID textile by inserting rows of 6 horizontal 5.3cm(width) x 0.35cm (height) tags every 10cm pitch were made.

Then authors made a sample RFID shirt to evaluate the probability of apparel use. No damaged tags are found while cutting, sewing and steam ironing and a carpet by sticking the textile on vinyl carpet. (figure 1)

However manual manufacturing is clearly unfit for mass-production. At least one person has to stick to the woven machine to insert tags every setting pitch.

For enabling automatic manufacturing, we developed a method for automatic weaving with RFID tag yarn. 1.0m x19.0m RFID textile woven RFID tag every 10.0cm both horizontally and vertically were prototypically manufactured at this moment.

4 RFID Map Making System Development

The goal of the system is to make automatic ID map making system during the process of manufacturing the textile. This allows users to apply RFID based positioning system more casually since it saves large amount of time for integrating global position data and RF-ID. We focused on the ordinal textile inspecting process which is done at the very end of shipping. Usual inspection purpose is to check if there are any damages or weaving irregularities on the surface of textiles and length and width is consistent by both automatically rolling textile and measuring length by digital length measuring machine as well as being inspected visually within the area of a flat board. If RFID readers are mounted horizontally in the board region, it is possible to read a unique ID of each RFID tag-arranged yarn woven into the textile while inspection. We invented an inspection system along with automatic map-making system by developing 20 multi-scan 4.0mm (width) x 6.0mm (height) size antennas mounted on a custom made inspecting machine. (figure 3)

As figure 2 shows, the 20 antennas read within small area of each region and the reader transmits tag IDs and antennas' numbers consecutively every 250 msec. Besides the digital length measuring machine transfers a present y position of the textile by counting the number of rotations of a roller. Then the computer system records the first and the last distance of each RFID tag and calculates centre y position. (figure 2 right) X position is automatically calculated from an antenna's number as it is a fixed mounted position. The 19 m automatically woven RFID textile is inspected. (10 antennas every 10 cm pitch) The speed of rolling textile is 0.5m/min which means that mapping data (RFID tag ID and two-dimensional position) is automatically calculated and saved within 40 minutes.

Whereas manual work for making a mapping data of the same RFID textile took 22 hours by one person. Reading RF-IDs took two hours, measuring position by hand took 16 hours and making one mapping data file by organizing tag IDs and position data took two hours. Definitely the map making system saves much time for making a mapping data.

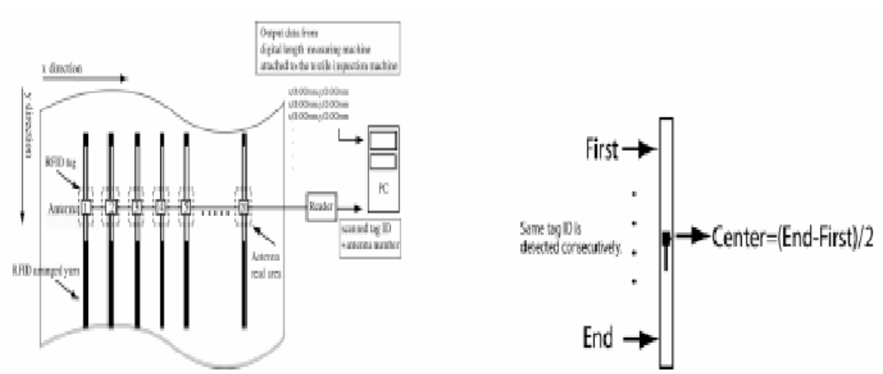


Fig. 2. Map-Making System Diagram (left) and vertical position calculation diagram (right)

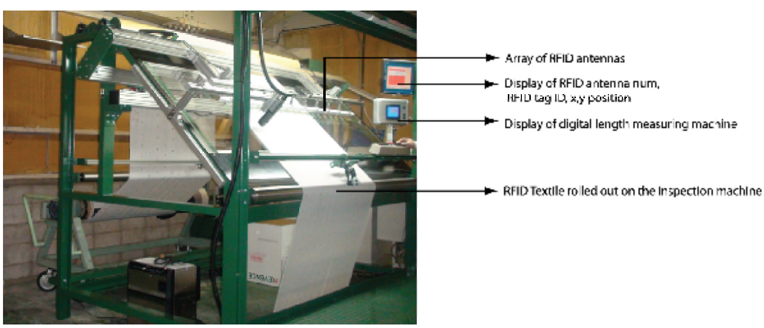
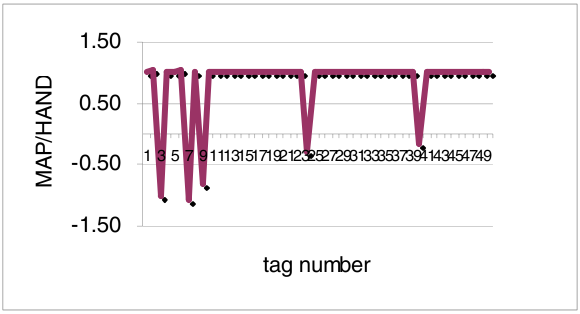


Fig. 3. Map-Making System

Table 1. Error ratio of measured by a map making system and measured by hand



For evaluating the accuracy of the calculated position of map making system, we compared the positions manually recorded (HAND) and the positions automatically calculated by the map making system (MAP). Horizontal position of 50 RFID tags in one line is evaluated. The length is about 4.8m. Table 1 shows error ratio calculated from each HAND value divided by each MAP value. There were five errors out of 50 tags. The position of 45 read tags were correctly measured

5 Human Activity Detection Applications

As for a practical application using RFID textile, authors present two types of position-based applications. First we apply RFID textile to a carpet and two readers are embedded on Japanese traditional shoes called 'Geta' so as to track a person's movement. Second, we apply RFID textile to a shirt and physical movement are detected by readers embedded in the environment.

5.1 Tracking on a Carpet

System outline of the tracking on a carpet and prototype shoes are shown in figure 4. The RFID textile carpet size is 1.0m x 19.0 m. The pitch of RFID tags are every 100mm horizontally and every 100 mm vertically. RFID reader system is embedded on the bottom of left and right shoes. RFID reader is connected wirelessly to a server PC via Bluetooth ver 2.0 and transfers RFID tag ID by the request of the server PC consecutively. The average communication time between the server PC and the RFID reader to receive one RFID tag ID is 105msec (SD9.0msec) during 20000 trials. Coated RFID textile is shown in figure 5 left and tracking view is shown in figure 5 right.

The small scale of testbed were performed for evaluation of accuracy of position. The carpet size is 1.0m x 3.0m and tracking data of a left foot is recorded. Fig 6 shows a tracking of five straight steps. White line in the figure shows a tracking of 1.82m straight walking. The numbers on the line show the total number of times and locations RFID tags were detected. The reason that the tag detected numbers are more than the total number of walking steps is because the antenna consecutively calls

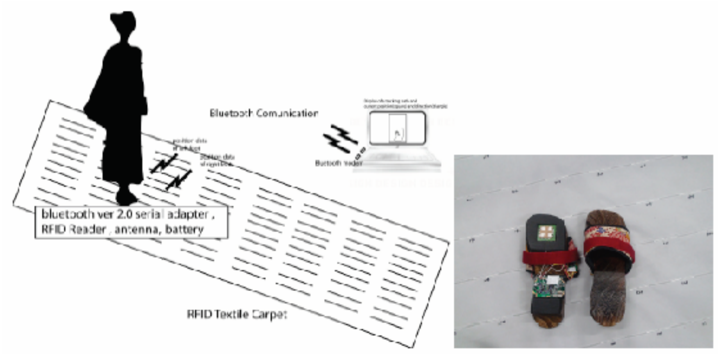


Fig. 4. System outline of a human-tracking system on a carpet and prototype shoes

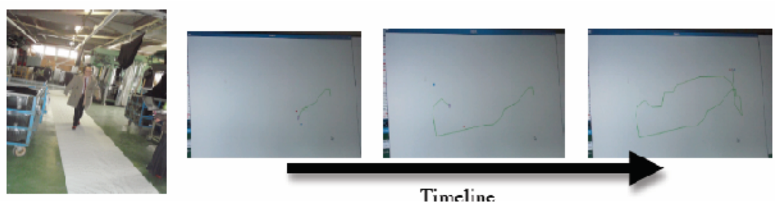


Fig. 5. A person walking on a RFID carpet (left) and tracking view (right)

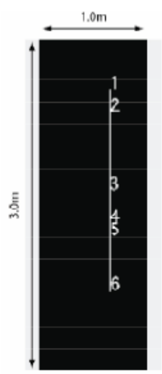


Fig. 6. 5 straight steps

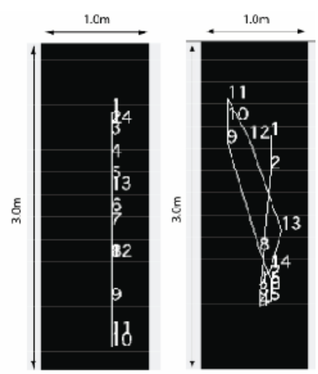


Fig. 7. 10 straight and random steps

nearest tags so that any tags within accessible area is read even if the antenna is not touched on the carpet. However reading frequency is randomly occurred which means that it's necessary to fill the missing tracks by simulating the distance and direction. Fig 7 shows another tracking's trials of 10 straight and random steps.

Fig. 8. RFID textile shirt (left) and behavior logging environment (right)

5.2 Behavior Logging

System outline of a behavior tracking is shown in fig 8. A RFID textile shirt (Fig.8. left) has 55 tags. Tags are categorized as each body part. Prototypically, we categorized seven parts of the body. (left upper arm, left arm, right upper arm, right arm, front left, front right and back) If a wearer touches one of the readers while his/her activity, the reader detects one of the tags in the wear, which automatically determines which body part is touched. We tested one antenna embedded in a desk surface around a computer mouse area. We assume this system unobtrusively makes a behavior logging to detect who, where, when, what. Further experiments are necessary for further discussions.

6 Conclusions and Future Works

We presented RFID textile and a map making system we have developed. These were effective for making location aware systems in real use because RFID textile was possible to cover large space at once. Also, by automatically making a mapping table under the process of manufacturing textile, the location aware system was able to work immediately after the textile was set. These characteristics will save much cost and time for the installation. We found the map making system skipped reading RF-ID while testing. Achieving 100 % RF-ID read and increasing inspection speed are our next challenge. We also presented two prototypical location based applications. The basic function worked well for both applications. But there were some missing of RF-ID while walking when the shoe was in dead area of the beacon. We will perform further experiment to evaluate the error rate of it and challenge to decrease the error rate. As for RFID textile wear, the novel human activity tracking method is expected. We will continue to set up an experimental space in a laboratory room for logging an ordinary activity.

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References

1. Meyer, S., Rakotonirainy, A.: A Survey of Research on Context-Aware Homes. In: Workshop on Wearable, Invisible, Context-Aware, Ambient, Pervasive and Ubiquitous Computing, vol. 21, pp. 1–10 (2003)
2. Ravindranath, L., Padmanabhan, N.V., Agrawal, P.: SixthSense: RFID-based Enterprise Intelligence. In: Proceedings of MobiSys 2008, pp. 253–266. ACM Press, New York (2008)
3. Konomi, S., Roussos, G.: Ubiquitous computing in the real world: lessons learnt from large scale RFID deployments. In: Personal Ubiquitous Computing, pp. 507–521. Springer, Heidelberg (2007)
4. Amemiya, T., Yamashita, J., Hirota, K., Hirose, M.: Virtual Leading Blocks for the Deaf-Blind: A Real-Time Way-Finder by Verbal-Nonverbal Hybrid Interface and High-Density RFID Tag Space. In: Proceedings of the VR 2004, pp. 165–172. IEEE Publishing, New York (2004)
5. Gharpure, C., Kulyukin, V., Jiang, M.-h., Kutiyanawala, A.: Passive Radio Frequency Exteroception in Robot Assisted Shopping for the Blind. In: Ma, J., Jin, H., Yang, L.T., Tsai, J.J.-P. (eds.) UIC 2006. LNCS, vol. 4159, pp. 51–60. Springer, Heidelberg (2006)
6. Scooter, S., Helal, S.: A passive rfid information grid for location and proximity sensing for the blind user. In: University of Florida Technical Report number TR04-009 (2004)
7. Bohn, J., Mattern, F.: Super-distributed RFID Tag Infrastructures. In: Markopoulos, P., Eggen, B., Aarts, E., Crowley, J.L. (eds.) EUSAI 2004. LNCS, vol. 3295, pp. 1–12. Springer, Heidelberg (2004)
8. Smart carpet, vorwerk and co. (2006), http://www.vorwerk-teppich.de
9. Smith, R.J., Fishkin, P.K., Jiang, B., Mamishev, A., Philipose, M., Rea, D.A., Roy, S., Sundara-Raian, S.: Rfid-Based Techniques for Human-Activity Detection. Communications of the ACM 48(9), 39–44 (2005)