A WEARABLE RFID SYSTEM FOR REAL-TIME ACTIVITY RECOGNITION

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Abstract—

Elderly care is one of the most important aspect which have real-time activity recognition systems applications. Many other approaches of activity recognition can be done by the use of advanced cameras for monitoring, inertial sensors, depth cameras, body sensor networks. However these have various limitations due to privacy issues, coverage, ease - of-use, non-economical. with the rapid advancement of wireless networking in the recent years, We can recognize a person's activities based on wearable sensors. In this paper, we present a radio frequency identification (RFID) system to provide a high ease-of-use and to monitor the real time activities of a person. Our system uses a Micro electro-mechanical sensor (MEMS) and a small RFID system(RFID reader along with passive tags), RFID system is for extended detection coverage of the person. We develop a system so as to easily monitor the body movements of a person on a smartphone. By the use of this Recognition method the advantages are of Low-cost with high reliability and also have less packet loss ratio. We have accuracy around 90% with response time of around 10 seconds. We use RFID in range of HF because if we go for UHF, system attenuation occurs at higher rates due to human body interference and it also leads to higher costs along with maintenance issues.

Index terms—Activity recognition, wearable RFID system, MEMS

I. INTRODUCTION

Real time activity recognition plays a major role in many applications as of in elderly care as the number of elder people are increasing day by day in the world. With the reduction of the costs in wireless sensing devices, there is a trend in deploying the body sensor network (BSN) as the solution for the human centric applications like elderly care, health monitoring [1], activities of the person inside a building [2]. Many new applications are under active development to provide support for elderly people with diseases and impairments. Smart remainder system for people with memory impairment to monitor person's activities and set remainders when the daily routine is not followed [3]. Emergency response systems for falling detection and dangerous behavioral movements of a person[4]. Independent physical activity recognition systems for long time activity/health monitoring[5]. Using activity recognition systems for the elderly people poses many challenges especially with the people with physical and mental impairments as they do not have **ease-of-use—**As most of the systems are designed for personal usage purposes which lag in the professional

supervision. So, For these kind of people we need to maintain a minimum effort continuously to maintain and re-configure the system. **coverage—**Many experiments for wireless communication for activity recognition by the means of Body Sensor Networks(BSN) were done but, By the use of BSN, The packet delivery ratio/accuracy is reduced because of the impermeability of the human body. So, obtaining the data/sensor readings at low power becomes a challenge[1]. **Cost—**To increase the efficiency of the system we may use sensor node at higher power levels but this in turn increases coverage and further more security problems, Although privacy can be achieved but the extra energy overloads leads to high cost and maintenance.

Due to the fact of privacy Invasiveness of the computer based approaches, Wearable sensors based approaches have been widely adopted for the activity recognition [6]-[11]. So, to capture the sensor data which is related to the person's activities, Smartphone's/sensor nodes are worn on the person's body. These sensor nodes form a Body sensor network (BSN). Earlier and existing works have shown the effectiveness of these wearable sensors which have high- coverage abilities for activity recognition. However these may not be applicable for the elderly people because of the ease-of-use problems like the sensitiveness to the sensor displacement [12] and constant requirement of battery maintenance [13].So, In order to address the above limitations recent works mainly explore for the device-free activity recognition approaches by the use of RF signals [14]-[16]. So here we use only a single sensor and by this avoiding many sensors and sensor nodes to reduce the limitations of maintenance and ease-of-use. By the above approaches compared to the BSN approaches we pose no or minimum requirements on the person to wear devices for activity recognition as the transmitting/receiving devices are located near to the user, Limitation of coverage area is by the user's mobility/movements. Much work has been done to get the best activity recognition accuracy in the home setting[2], Studies and scope lies on the importance to provide wide detection coverage and so involving the person/user to the outdoor activities[17].

In this paper we propose a novel approach as the proposed system uses RF signals for detecting the passive RFID tags which in turn helps for the location of a person inside a building. We use the passive tags as they are of low-cost, Battery free and encapsulated devices that can be set on any area/location, these can be even easily wearable by the user. Once installed, these passive tags require no further maintenance efforts as of the BSN nodes and can even survive in harsh environments/conditions. Our system uses a RFID reader and this reader is equipped on the user's body along with other modules. Efforts were taken to increase the coverage and the accuracy in the readings by reducing the wearing and maintenance of the RF-based approach of the activity recognition[18].

A sensor system is proposed in this paper which is based on micro electro-mechanical sensor (MEMS). The micro-mechanical device which is embedded with electronic/electrical system and fabricated through IC manufacturing and micro-machining process. In this micro machining process the material is shaped by etching away the micro layers and so called MEMS.We use MEMS because of it's compact size and volume, it is cheaper and has a very low power consumption, It is highly resistant to heat, shock, vibration with improved thermal expansion tolerance. The use of MEMS can be found everywhere in consumer appliances, automobiles, computer peripherals, military, bio-technology and so on.In this project we use a 3- Axis orientation/Motion detection sensor(A low profile capacitive MEMS sensor featuring upto 6-bit data samples per second or at the rate of user configuration), with the weight of the sensor around 1.5 grams.

In our project we propose a system with indoor location sensing or the location sensing with a very less radius by implementing the very easily accessible wireless devices so that we can make use of the existing infrastructures, 802.11, infrared, RFID, ultrasonic are the types of location sensing systems each having their own strength. In this paper we implement 802.11b (Wi-Fi) standard from transmitting the data from the reader module to a reading device (Laptop/smartphone) in a specific range.

To sum up, this paper gives the following contributions :-

- A wearable RFID reader module and use of passive tags helps in high coverage area which is suitable for elderly care.
- The use of MEMS sensor to know the Real-time activities of the person for activity recognition.
- Data from the sensor is processed and sent to smart devices over a 802.11b standard (Wi-Fi) module, so it will be easier to track/monitor real-time activities and address the person when fall detection occurs.
- Various movements of the subject are tested and verified the time of response under the subject's abnormal movements/positions.

II. RELATED WORK

2.1 wearable sensor – based activity recognition

Much work has been done using the BSN's for activity recognition [6]-[11]. These deploy many accelerometer sensors on the subjects body to capture the body movements. By implementing certain types of MAC and routing protocols they set these sensor nodes for better quality of the sensor data. Advantage of BSN is that they provide high coverage and fine-grained activity recognition as the user wears the sensors and moves. But, because of their limitations they are not widely adopted for elderly care applications. One of the issue is caused by sensor displacement [5] and another limitation is that the sensor nodes are battery powered and constant maintenance to the system must be done by checking, charging, replacing batteries. So, differently we use the RFID system for location sensing in activity recognition. The advantages of them are of low cost, easy maintenance especially the passive tags of RFID does not need any maintenance [19]. Because of use of low cost passive tags our system becomes more energy efficient when compared to the use of BSN's. By the use of a smartphone based system we track the subject/person's movements easily on our smartphone. The use of smartphone based activity recognition system has increasing its usage [7]-[10]. But in [7] the authors use the Smartphone's in-built accelerometer to perform the activity recognition by placing the phone in the front pocket's of the user's pants. In [9] authors use of combination of sensor nodes and also smartphone is for practical activity recognition. Apart from the above work, we only use the smartphone to monitor the sensor positions which are displaced on a smartphone with the help of the Wi-Fi module. Activity sensing is done by the MEMS sensor which is set at the chest position of the subject and we use the RFID tags for location sensing indoors.

2.2 Real-time activity recognition

Apart from the use of sensor for detecting the position of the subject there are many approaches with and without the use of the sensors for real time activity recognition. Various RF-based approaches have been proposed to perform the activity recognition with a device free manner, In this approach user requires no or minimum number of devices to perform the activity recognition. [20] Describes the activities of the users by using the Wi-Fi signals where user is involved in gestures and moving [20,21] breathing and heart beat[22].

The detailed information is obtained by the signal strength of different frequency bands that are extracted from reflecting Wi-Fi signals from the person's body to detect their activities.Recent researches are done on the backscatter technology which have attracted much interest because of the low-cost and low-power properties. Various researches have been done on this technique especially for activity recognition[23-25].Various works include LANDMARC [19] and TASA[14] which track the activities of the user/subject by using fixed RFID and tag arrays. These capture the patterns of the RFID signal by mobility of objects to perform accurate tracking and localization.The author's of [1] use radio patterns extracted/collected from a BSN to recognize the user activities. These patterns are estimated based on the arrival packets within a time window are extracted and used as a reference to recognize the corresponding activity. In[18], authors use a tracking of motion of objects behind the walls by organized network of sensor nodes. Different links across the area is measured and recorded, the variance values caused by moving objects is computed and processed by "Variance-based radio tomography imaging algorithm".The work presented in this paper differs from the above mentioned approaches in the following pints. Most of the existing RF-based approaches gives only the availability of fixed transmitter/receiving devices which are located near the user [14]- [16] [18] [20] [22] [26-29] with this the coverage area becomes limited, this work achieves a high coverage area by the use of tags at specific location of the building so as to detect the area in which the user is present. We only use a single sensor with high precision and the response time of the sensor is too quick, so it will be easy for the data collection for activity recognition. Secondly, some works depend on specialized devices to capture the readings. Though such devices now-a-days are easily available, In this work we use a general purpose processor which is quite affordable and its fast processing helps in taking better reading from the sensor. Unlike the use of BSN we use the passive RFID technique and implement a single MEMS sensor with a 3-axis orientation/motion detection to reduce the maintenance and increasing the activity recognition.

III. PRELIMINARY EXPERIMENTAL STUDIES

3.1 Hardware setup

In this section, we introduce our setup and conduct the preliminary experimental results to show the tag readings and it's performance characteristics under other controlled conditions and other for activity recognition.We use a RFID reader module (EM-18) for RFID tag readings. It has a reading distance range of upto 10cm (for the prototype) with a operating frequency of 125khz. The size of the reader module is 32mm(length) × 32mm(width) × 8mm(height). This has a 5v input. We use the RFID tags of the credit card size (we use passive tags). RFID tags are used to locate the person's location inside a particular setting or location (we can even say it might be a home setting). We use a MEMS sensor (MMA7660FC) for gathering the data on person's movements or positions. MMA7660FC is a 3- axis orientation/ motion detection sensor which is around 1.5 gms with a digital output. As the sensor has a digital output, we use a ARM7 processor of LPC214x series to analyze the output and send it to a reading device (we use a LCD device on the circuit board and also we use a smartphone to read the output for the prototype) The input operating voltage of MEMS is of 2.4-3.6 volts and a temperature range of operating is -40 to +85□. The output of the processor is sent to a smartphone for easy accessibility of viewing. The data from the processor is sent to a smartphone with the help of a Wi-Fi module (Wio4). Tag readings obtained from the reader are sent wirelessly through a serial-to Wi-Fi adapter and the readings are received over a smartphone. We use a Motorola G4plus smartphone running over Android 7.1 and has a 1.5Ghz octal-core processor.

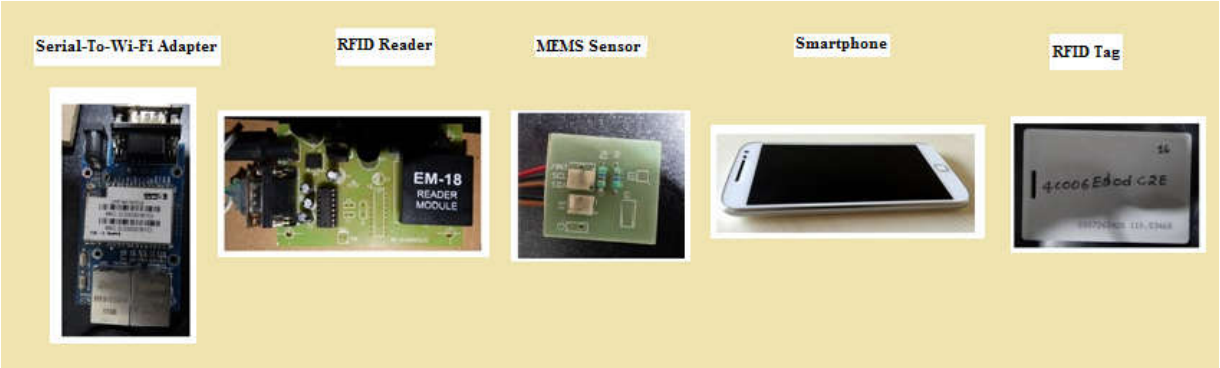

Fig. 1. Components used

3.2 Reading RFID Tags

RFID tags used in our project are to increase the coverage area/ usability of our equipment. We use the passive tags as they require no further maintenance and are easy to use. We use these passive tags in specified locations of a particular area (for suppose we use two tags in two rooms of a building and give them as area1 and area2). Whenever the reader module comes in range with the tag it gives the location update to the Smartphone through a Wi-Fi module (from the output of the processor after analysis). With the help of the 16-bit EPC over a RFID tag we feed its data to the processor (we use the 16-bit electronic product code [EPC] stored on the tag as it's ID).

3.3 Potential Of Activity Recognition

All the hardware equipment i.e., the processor, the reader module and the Wi-Fi module are placed on a board and are mounted at the waist of a person/subject (for the proto-type model). The MEMS is attached to the chest area if a person (directly over the skin on the chest as MEMS is a highly sensitive capacitive accelerometer). The output of MEMS are given to a processor (MEMS has a digital output). With the use of MEMS we have the advantage of low power consumption, compact size, portability, high detection sensitivity and many more.

So, the person with all the mounted equipment is observed when the subject is carrying out various basic motions of bending forward, bending backward, left or right. Whenever the sensor detects a freefall situation then the alert will be sent to the Smartphone along with a loud buzzer is activated (remember that we use the project for elderly care and however we have not used a buzzer in this proto-type model).

The time duration for the detection in the change of a motion is around 5 to 10 seconds which we can give it as a time resolution and the minimum angle with which the change can be detected is greater than or equal to 45 degrees (between 45 to 90degrees). The equipment of the sensor is completely fixed at the chest of the person/subject to get the maximum readability and we can achieve maximum possibility in results.

All the readings from the sensor are analyzed by the processor and then sent to the Smartphone and we can easily track the movements of the subject from time-to-time. All the above description is given in the figure2 where we have used all the hardware including the processor.

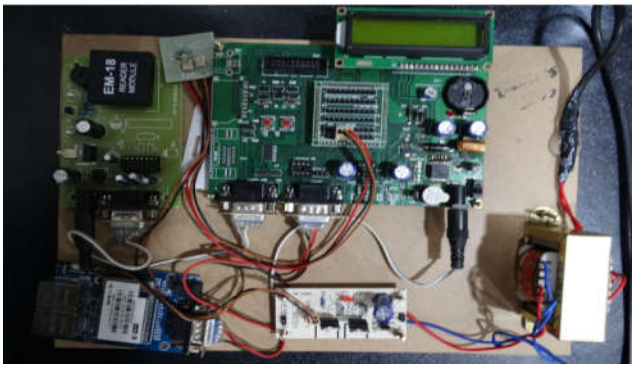

Fig.2. Hardware setup

IV. SYSTEM DESIGN

The above preliminary studies have shown the potential of using the reader and the RFID tags for activity recognition. In this section, we give a detailed design of the RFID based real-time activity recognition system including the sensing, data processing, data transferring and the algorithm developed to get the activities done by the subject.

4.1 Tag Placement

We only use the RFID passive tags to find out the subject's location (for example in a particular room of a building). We attach the tags in particular areas of the rooms or for suppose simply at the entrance of the room. This placement strategy ensures that no matter how, It will have no error in recognition as the person/subject will have no other way to enter a particular area (it's just like a particular employee entering into a high-end facility only after gaining certain access).

As said above, with the electronic product code we develop an algorithm, so as to identify the area in which the subject is located can be traced whenever we get a particular tag reading. Here, the reader module is the key so that we will be able to recognize the area/location of the person. So, the entire performance is dependent on the reader module. The system performance of recognition accuracy and battery consumption is dependent on the power of the reader module (so, in order to make it less expensive we use a basic reader module of 10cm reading range as we use it only for testing purpose).

4.2 Data Analysis

Given that we use a 3- Axis accelerometer, in our project we detect the body movements like bending forward, bending backward, turning left, turning right and a normal movement. If there is anything other than these movements the sensor detects fall and gives shake detection called as tilt. This tilt can be set based on our requirement by setting the axis range of the sensor based on the axis movements. By using the serial clock and serial data input of the sensor we connect the sensor to the processor and the readings are analyzed by the processor and the readings are sent to the Smartphone after analyzing the sensors data by the processor (about the current position of the subject). Whenever there is a change in the orientation of the sensor, the Smartphone is updated with the current position if the subject and ones there is a fall detection TILT is observed at the sensor end and a alert is passed to the Smartphone. We use a 16 by 2 LCD on the prototype for easy analysis of the data and our proto-type working (we can even implement our project without LCD also).

4.3 Real-Time Recognition Algorithm

The main goal of our system is to achieve real-time recognition. So for that we need mainly two requirements

Online. In [30] authors present a offline recognition system where they cannot perform real-time recognition because they need to wait for the current activity to finish before recognition and waiting time will be uncertain. The algorithm for real-time recognition must be online which can be recognized but not after the complete activity has happened. Here we apply a Wi-Fi transmitter to immediately send the data in the pre-described range. By this data will be already available even before the next instance is completed.

Continuous. To achieve the real-time recognition we need to get the data before the delay bound and it should be regularly monitored. So for this purpose to make the monitoring work easy we use a smartphone for monitoring purpose and all the data collected is transferred to it by using a Wi-Fi transmitter.

V. CONCLUSION

Here, we present a RFID-based system for Real-time activity recognition as we aim in providing a easy usage of solution with high detection capacity by the use of MEMS which supports the applications like elderly care. We implement a proto-type model and the results are pretty satisfactory, apart from the time taken for recognition process, we get a very high possibility of movement detection without much delays as this is only a prototype model. By the use of the Wi-Fi module and a smartphone with tags we gain a higher accuracy in detection of the subject along with the area location. As of this initial work, the limitations of our system is that firstly, RFID systems are still cumbersome for wearing. We use a RFID reader for reading tags which is included in the system which the subject wears and this makes the wearing system much more complex. Secondly, for the easy access in the readings we use a smartphone and a wi-fi transmission module. The Wi-Fi module consumes much more power as it should continuously on while the prototype is installed.

So, as a result we use much more hardware and so, we require much more power for all the modules combined. We use a development board of the processor rather than a specific purpose processor for this prototype model. So finally as a result our whole system might be slightly complex for the subject to wear. So other than the use of the RFID systems we are working on areas of other detection mechanisms and the usage of much more optimized hardware solutions for mobile applications.

REFERENCES

[1]. X. Qi, G. Zhou, Y. Li, and G. Peng, “Radiosense: Exploiting wireless communication patterns for body sensor network activity recognition,” in Proceedings of the 33rd IEEE Real-Time Systems Symposium (RTSS), 2012, pp. 95–104.

[2]. T. Van Kasteren, A. Noulas, G. Englebienne, and B. Kr¨ose, “Accurate activity recognition in a home setting,” in 10th International Conference on Ubiquitous Computing. ACM, 2008, pp. 1–9.

[3]. M. E. Pollack, L. Brown, D. Colbry, C. E. McCarthy, C. Orosz, B. Peintner, S. Ramakrishnan, and I. Tsamardinos, “Autominder: An intelligent cognitive orthotic system for people with memory impairment,” Robotics and Autonomous Systems, vol. 44, no. 3, pp. 273–282, 2003.

[4]. T. Lee and A. Mihailidis, "An intelligent emergency response system: preliminary development and testing of automated fall detection," Journal of Telemedicine and Telecare, vol. 11, no. 4, pp. 194–198, 2005.

[5]. A. M. Khan, Y.-K. Lee, S. Lee, and T.-S. Kim, "Accelerometers position independent physical activity recognition system for long-term activity monitoring in the elderly," Medical & Biological Engineering & Computing, vol. 48, no. 12, pp. 1271–1279, 2010.

[6] T. Gu, L. Wang, Z. Wu, X. Tao, and J. Lu, "A Pattern Mining Approach to Sensor-based Human Activity Recognition," IEEE Transactions on Knowledge and Data Engineering (TKDE), 2010.

[7] J. R. Kwapisz, G. M. Weiss, and S. A. Moore, "Activity recognition using cell phone accelerometers," ACM SigKDD Explorations Newsletter, vol. 12, no. 2, pp. 74–82, 2011.

[8] Z. Zhao, Y. Chen, J. Liu, Z. Shen, and M. Liu, "Cross-people mobilephone based activity recognition," in International Joint Conference on Artificial Intelligence (IJCAI), vol. 22, no. 3, 2011, p. 2545.

[9] M. Keally, G. Zhou, G. Xing, J. Wu, and A. Pyles, "Pbn: towards practical activity recognition using smartphone-based body sensor networks," in 9th ACM Conference on Embedded Networked Sensor Systems. ACM, 2011, pp. 246–259.

[10] A. Henpraserttae, S. Thiemjarus, and S. Marukatat, "Accurate activity recognition using a mobile phone regardless of device orientation and location," in 2011 International Conference on Body Sensor Networks

(BSN'11). IEEE, 2011, pp. 41–46.

[11] A. Parate, M.-C. Chiu, C. Chadowitz, D. Ganesan, and E. Kalogerakis, "Risq: Recognizing smoking gestures with inertial sensors on a wristband," in 12th International Conference on Mobile systems, Applications, and Services. ACM, 2014, pp. 149–161.

[12]A. M. Khan, Y.-K. Lee, S. Lee, and T.-S. Kim, "Accelerometers position independent physical activity recognition system for long-term activity monitoring in the elderly," Medical & Biological Engineering & Computing, vol. 48, no. 12, pp. 1271–1279, 2010.

[13] G.-Z. Yang and M. Yacoub, "Body sensor networks," 2006.

[14] D. Zhang, J. Zhou, M. Guo, J. Cao, and T. Li, "Tasa: Tag-free activity sensing using rfid tag arrays," IEEE Transactions on Parallel and Distributed Systems (TPDS), vol. 22, no. 4, pp. 558–570, 2011.

[15] J. Wang, D. Vasisht, and D. Katabi, "Rf-idraw: virtual touch screen in the air using rf signals," in 2014 ACM conference on SIGCOMM (SIGCOMM'14). ACM, 2014, pp. 235–246.

[16] W. Wang, A. X. Liu, M. Shahzad, K. Ling, and S. Lu, "Understanding and modeling of wifi signal based human activity recognition," in 21st Annual International Conference on Mobile Computing and Networking. ACM, 2015, pp. 65–76.

[17]H. Mollenkopf, F. Marcellini, I. Ruoppila, P. Flaschentr¨ager, C. Gagliardi, and L. Spazzafumo, "Outdoor mobility and social relationships of elderly people," Archives of gerontology and geriatrics, vol. 24, no. 3, pp. 295–310, 1997.

[18]J. Wilson and N. Patwari, "See-through walls: Motion tracking using variance-based radio tomography networks," IEEE Transactions on Mobile Computing (TMC), vol. 10, no. 5, pp. 612–621, 2011.

[19] L. Ni, Y. Liu, Y. Lau, and A. Patil, "Landmarc: indoor location sensing using active rfid," Wireless networks, vol. 10, no. 6, pp. 701–710, 2004.

[20]F. Adib and D. Katabi, "See through walls with wifi!" in 2013 ACM conference on SIGCOMM (SIGCOMM'13), vol. 43, no. 4. ACM, 2013.

[21]M. Li, P. Zhou, Y. Zheng, Z. Li, and G. Shen, "Iodetector: A generic service for indoor/outdoor detection," ACM Transactions on Sensor Networks (TOSN), vol. 11, no. 2, p. 28, 2014.

[22]F. Adib, H. Mao, Z. Kabelac, D. Katabi, and R. C. Miller, "Smart homes that monitor breathing and heart rate," in 33rd Annual ACM Conference on Human Factors in Computing Systems. ACM, 2015, pp. 837–846.

[23] D. Bharadia, K. R. Joshi, M. Kotaru, and S. Katti, "Backfi: High throughput wifi backscatter," in 2015 ACM Conference on SIGCOMM (SIGCOMM'15). ACM, 2015, pp. 283–296.

[24] P. Hu, P. Zhang, and D. Ganesan, "Laissez-faire: Fully asymmetric backscatter communication," in 2015 ACM Conference on SIGCOMM (SIGCOMM'15). ACM, 2015, pp. 255–267.

[25] P. Zhang, P. Hu, V. Pasikanti, and D. Ganesan, "Ekhonet: High speed ultra low-power backscatter for next generation sensors," in 20th Annual International Conference on Mobile Computing and Networking. ACM,
2014, pp. 557–568.

[26] Y. Wang, J. Liu, Y. Chen, M. Gruteser, J. Yang, and H. Liu, "E-eyes: device-free location-oriented activity identification using fine-grained wifi signatures," in 20th Annual International Conference on Mobile Computing and Networking. ACM, 2014, pp. 617–628.

[27] L. Yao, Q. Z. Sheng, W. Ruan, T. Gu, X. Li, N. J. Falkner, and Z. Yang, "Rf-care: Device-free posture recognition for elderly people using a passive rfid tag array," in 12th International Conference on Mobile and Ubiquitous Systems: Computing, Networking and Services, 2015.

[28] K. Joshi, D. Bharadia, M. Kotaru, and S. Katti, "Wideo: Fine-grained device-free motion tracing using rf backscatter," in 12th USENIX Symposium on Networked Systems Design and Implementation (NSDI 15). USENIX Association, 2015.

[29]P. Asadzadeh, L. Kulik, and E. Tanin, "Gesture recognition using rfid technology," Personal and Ubiquitous Computing, vol. 16, no. 3, pp.
225–234, 2012.

[30] A. Avci, S. Bosch, M. Marin-Perianu, R. Marin-Perianu, and P. Havinga, "Activity recognition using inertial sensing for healthcare, wellbeing and sports applications: A survey," in 23rd International Conference on Architecture of Computing Systems. VDE, 2010, pp. 1–10.

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