Journal of Ubiquitous Systems & Pervasive Networks
Volume 6, No. 1 (2015) pp. 33-39

End-to-End Safety Solution for Children Enabled by a Wearable Sensor Vest

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Abstract
Mobile and wearable sensors are increasingly becoming an important part of our lives in securing everyday actions, monitoring and controlling our health and well-being. This paper presents an end-to-end safety service for parents and teachers in day-care centers and schools, including a prototype wearable vest with various sensors monitoring the environment and presence of children. Teachers and parents are able to receive alerts and notifications, e.g., when a child moves across certain restricted outdoor or indoor area, through gateways that have connectivity to server or cloud. All the information gathered by the vest is made available utilizing Sensor Web Enablement (SWE) services to guarantee a standardized way to manage the data coming from multiple sources. The vest is part of a larger framework to provide digital safety applications and services through various sensor devices.

Keywords: *Wearable Computing, Safety, Children, Sensor, LilyPad Arduino, Adafruit Flora, Sensor Web Enablement*

1. Introduction

There is an increasing need to have easily deployable and autonomous technical devices to support the safety and well-being of children in day-care centres and primary schools. Additionally, these new devices should also ease the burden of the respective teachers in their daily routines. Therefore, carefully designed solutions could provide more resources and time for the actual duties of teachers, instead of spending time on safety issues. However, children as technology end-users are many times being neglected in the development of new technologies, even though the environment of their growing-up has dramatically changed during the last decades.
There are already a great variety of sensors and devices deployed in schools, roads and at homes, and more are expected in the near future. The different mobile and wearable devices with embedded sensors enable monitoring of personal behaviour and physiological signals. Utilizing these multiple sensors and the information that they provide is not straightforward, as often the data is not easily accessible or available. Also difficulties arise, when managing the multi-sensor data in order to make intelligent reasoning, and to be able to draw conclusions about the children's safety and well-being.
In our work, we have developed a comprehensive end-to-end solution ranging from a wearable sensor vest to sensor deployment and interoperability implementing an extensive service framework. The wearable safety vest would automatically provide information about the presence or absence of children from their restricted outdoor or indoor area. In addition, the vest would gather other sensor information about the overall well-being, behaviour and activity of the children. Context-aware applications offer real-time and secured information, with partially dedicated views for, e.g., teachers at school and parents, utilising a variety of sensors from the surroundings of the children.
Our safety vest framework consists of three main building components:

- Two demonstration safety vests equipped with LilyPad Arduino [10] and Adafruit Flora [1] controllers that collect information from sensors and send it wirelessly through the Zigbee (IEEE 802.15.4) based XBee [11] radio module to the Galileo [17] or Raspberry Pi [31] network gateway.
- Standardized Sensor Web Enablement (SWE) services, in our case Sensor Observation Service (SOS), which makes the multi-sensor data available to different web applications and services.
- Context-aware end-to-end applications and services providing real-time information to the end users.

At the moment, we have equipped the vest with an XBee radio module, GPS (Global Positioning System), temperature and accelerometer sensors but the platform technicalities do not restrict it from including other sensors and radio modules in the future when available. Wearable solutions and computing are a

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DOI: 10.5383/JUSPN.06.01.005

growing area of products and markets, such as smart glasses, watches, activity buttons and wristbands (e.g. Google glasses, Samsung Galaxy Gear, Pebble Smartwatch, Polar Loop, Fitbit Flex etc.). Hence, additions to the wearable platforms such as LilyPad and Flora should be expected soon.

This paper extends our previous work shown in paper [19]. The rest of the paper is organized as follows. Section 2 introduces the related work in the areas of safety and well-being of children, and the design of novel services. This is followed by a system design, introducing the safety vest, sensor web enablement services, sensor applications and end-to-end safety framework in Section 3. Section 4 presents the gateway implementation with localization algorithms. Conclusions and suggestions for future work are discussed in Section 5.

2. Related Work

In recent years, there has been a growing interest in research and development into different wearable and monitoring systems. However, most of the developed solutions aim to answer certain dedicated health, activity, and/or security issues, while a large-scale system answering different system requirements, and also suitable for common use e.g., by teachers, parents, and school nurses, is missing.

Developing monitoring systems for ubiquitous care for children is presented in [26]. Their developed system, "UbicKids", focuses on three main aspects, such as children's awareness, assistance, and advice. In [23], the focus is on the design of a wearable device for children under six years old. The system gathers biological and physical information such as heart rate and body movements, and it also includes GPS and a camera. KiMS is a monitoring system for the early detection of symptoms for various diseases, as well as encouraging children towards healthy habits and activities [4]. Wearable acoustics sensors are used to detect audio signals, such as coughs, sneezes, and crying. In addition, body temperature and pulse rate sensors are combined into the system. In [7] the use of spectral analysis techniques for multiple sensor data for a child's activity recognition is proposed. An accelerometer, air pressure sensor and gyroscope are utilised to detect, e.g., walking, lying down, running, climbing stairs, jumping and standing up. In [16] a similar wearable device with a camera, accelerometer, GPS and a heart rate monitor is developed to detect activity modes.

Health- and activity-related systems are among the most commonly developed and researched ones, but another popular and important aspect related to the monitoring of children concerns the safety issues of children. The implemented design in [16] also monitors children through various sensors, and creates activity modes that are in contact to provide an alert of any abnormalities between children and to detect potential emergency situations. A similar design of a system for detecting dangerous situations along children's school routes is described in [34]. The architectural implementation of the system is described in [35].

The work in [18] describes a device to detect isolated children on field trips, based on Received Signal Strength Indicator (RSSI) values. In [20], the focus is on the protocol development of a location-based child safety care service, taking into account the related privacy issues, and an extended description of this system can be found in [21]. Furthermore, in a field study by Ervasti et al. [12], an attendance supervision system for primary school pupils was introduced and trialed, supported by Near Field Communication (NFC) technology. The system replaced manual roll calls and gave parents real-time information on their children's attendance details at school and extended day-care programs. There are also commercial applications and devices to monitor children's safety and well-being already available on the market. Some of the latest solutions include: RFID (Radio Frequency Identification) tags for school uniforms [22], GPS wristwatches, sensors measuring human emotions (q-Sensor) [30], communication and location devices [14], and school bus and children's safety tracking systems (e.g. NorthStar [28]).

3. System Design

The preliminary system design has been an iterative process including many phases, such as analyzing the available "off-the-shelf" wearable sensor components, constructing the sensor vest prototypes, analyzing available middleware solutions and interfacing sensors, implementing the integrated system design and evaluating the design choices. The overall system architecture is presented in Fig.2, which consists of: embedded sensors including the sensor vest, sensor gateway, sensor bus implementation, SWE middleware services and the safety service applications for parents and teachers. More details about the web service composition approaches can be found in recent work from Mustafa et al. [27]. In the next subsections, the main building blocks and some findings from the implementations are explained in detail.

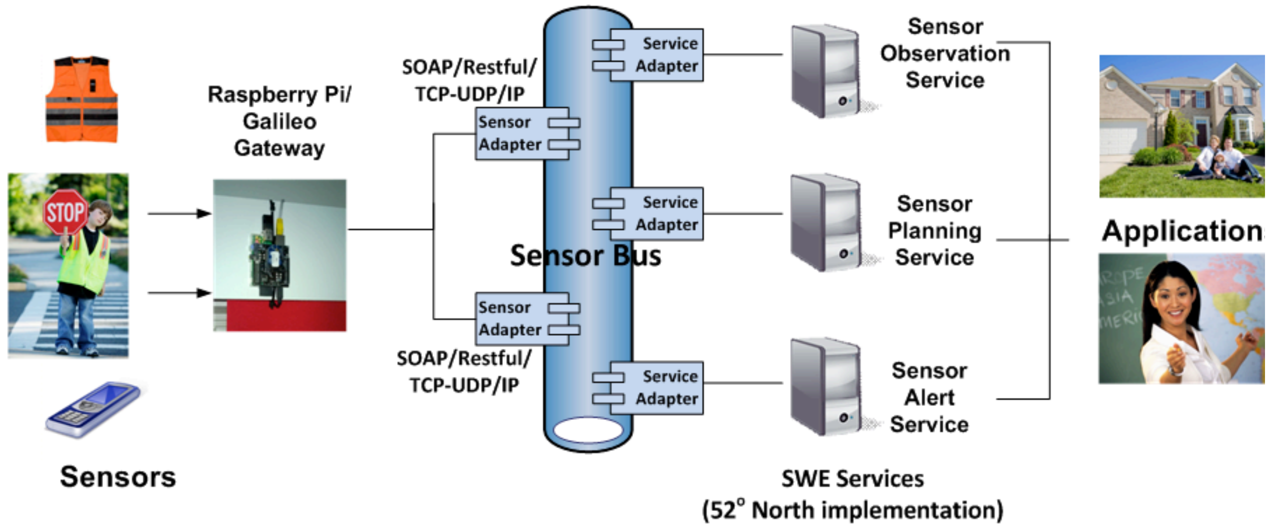

Fig. 1. System architecture

3.1. Safety Vest Design

For our safety vests (see Fig. 2), we chose two slightly different platforms: the LilyPad Arduino simple board and Adafruit's Flora board to test and compare the basic functionalities. They are microcontroller boards designed for wearables and e-textiles. These boards are used for integrating and collecting data from sensors and sending it wirelessly through the radio module to the gateway device. The vests include GPS, accelerometer and temperature sensors, and an XBee radio. The sensor components are specially designed for wearables. The vest configuration is summarized in Table 1.
In our design, the Body Area Network (BAN) consists of wireless and wired parts. Wired BAN transmits the data between sensors and microcontroller boards which are sewn together with a conductive thread to a separate piece of fabric as seen in Fig. 3. This way the system and a suitable place for the sensors can be more easily tested with a removable part for the components (yellow "pocket" in Fig. 2). The wireless BAN consists of the XBee radio part that makes the safety vest design automated and to be able to work in real-time sending the data to our safety application.

Fig. 2. Safety vest prototype

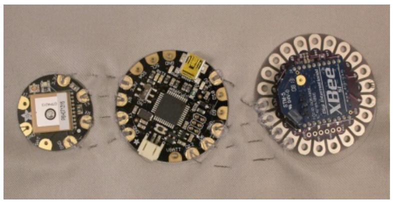

Fig. 3. Part of the sensor components

The simple board is a reduced version of the original LilyPad main board that also provided the inspiration for Flora. There are some differences between the two boards, as the Flora is slightly smaller than the LilyPad, and outputs a steady voltage of 3.3 volts, whereas the LilyPad outputs its input voltage. The LilyPad simple board however can charge its battery without additional circuitry. The USB (Universal Serial Bus) serial driver is built into the Flora whereas the LilyPad requires an external USB driver. It turned out to be easier to connect the components to the Flora, because it has more ground and voltage pins than the LilyPad. This allowed us to connect the components to the Flora without any crossings of the thread.
The physical communication between the vests and the gateway is handled by XBee Series 1 and 2 radios, which are based on the IEEE 802.15.4 standard. The range of the XBee radios is from 30 meters to 3.2 kilometers, depending on the environment, the XBee radio type, and the transmit power of the radio as specified by the manufacturer [11]. The microcontrollers run CoAP (Constrained Application Protocol) servers, which offer temperature, accelerometer, and GPS resources, depending on the configuration of the vest. Programming was done using Arduino IDE (Integrated Development Environment) and C++ as the programming language. The sensor data is read from the analog pins of the microcontroller and appended into a payload to be sent to the gateway.

Table 1. Vest configuration

Main board	LilyPad or Flora
Sensors	temperature, accelerometer
Radio-link	XBee 802.15.4
Localization	GPS (outdoor) and XBee (indoor)
Battery	850 mAh polymer lithium-ion

The power consumption of the systems can be greatly reduced by putting the XBee radios to sleep periodically. Without any power-saving techniques with the XBee Series 1 radio, and using a lithium polymer battery with a capacity of 850 mAh at 3.7 volts, the LilyPad vest can be operational for approximately 14 hours and the Flora vest for 10 hours. Flora vest is equipped with a GPS module, and therefore has shorter battery life. By putting the XBee radio to sleep for every other second, the LilyPad vest can achieve a battery life close to 24 hours. Approximately the same battery life can be achieved with the Flora vest by using the radio for one second every 30 seconds. The GPS module consumes a lot of power. Therefore, we have to use a longer sleep time for the radio in order to achieve the same battery life. This also means that the GPS data will be sent less frequently. Further improvements in battery life can be achieved by using sleep modes within the microcontrollers themselves.

3.2 Sensor Web Enablement

Nowadays it is possible to gather a great amount of information through multiple sensors but sharing, finding and accessing them across applications and services is not easy. The sensor suppliers utilize various proprietary and non-standardized protocols and communication methods, which make the integration and interoperability of sensors and devices very demanding in order to create a “Sensor Web”.
The Sensor Web Enablement (SWE) [9] initiative of the Open Geospatial Consortium (OGC) standardises web service interfaces and data encodings that can be used as building blocks for a “Sensor Web”. The suite of SWE standards enables sharing, finding and accessing networked sensors, transducers and sensor data repositories via the web.
The main OGC Standards in the SWE framework are: the SWE Common Data Model, providing data models and schema; the Sensor Model Language (SensorML) with models and schema for sensor systems and processes; Observations & Measurements (O&M) with models for packing observation values; the Sensor Observation Service (SOS) with a web interface for accessing observations; the Sensor Planning Service (SPS) for tasking sensor systems and requesting acquisitions; the Sensor Alert Service (SAS) for publishing and subscribing to sensor alerts; the Web Notification Service (WNS) for asynchronous notification and the SWE Service Model.
Our prototype implementation utilizes 52° North Initiative for Geospatial Open Source Software [38] implementation of SWE services [39]. In addition to this we used a modified version of their Sensor Bus implementation [40]. The Sensor Bus [8] establishes an intermediary layer between sensor networks and the ”Sensor Web” to close the conceptual gap between these two distinct layers resulting from different protocol stacks and data models.

3.3 Sensor Applications

Many different body movements can be recognized based on the accelerometer data [3], in order to provide and gather information about, for example, a child's activity level and behavior, to be utilized by numerous applications. The collected subsequent data can be utilized for analyzing certain patterns and changes in a person’s physiological state. The accelerometer can be used to measure acceleration as one-dimensional acceleration or tilt using three dimensions.
The basic identified activity modes can usually be categorized as walking, running, sitting or staying still, or using some form of transportation. Implementation of the vest has some limitations concerning the way the movement data is gathered compared to those wearable systems embedded with sensors that are situated in the arms or legs or in both of them. With arm and leg sensors, other more specific user activities can also be recognized, such as eating, using stairs, jumping, and lying down. In a recent paper from Strohrmann et al. [33] they showed that using three kinds of upper body sensors they are able to give real-time feedback to runners based on the arm carriage.
On the other hand, the components in our vest are attached to a separate piece of fabric, as shown in Fig. 2. This provides a way to more easily test and identify a suitable place for the sensitive components to guarantee the best system functionality and wearability. Also the possibility to complement the vest with other additional sensors in the future is much easier in order to apply more intelligent reasoning, context-awareness, and functional accuracy. Another advantage of using a vest is the usability and commonality, whereas there are safety vests already in a daily use in many nurseries and schools. The temperature sensor in the vest is used for environmental monitoring purposes. This sensor can assist teachers during extreme weather, to control when and for how long it is safe to stay outdoors during nursery and sport lessons. Knowing the temperature and its variations is also important for the well-being of those children who suffer from cardiovascular or pulmonary diseases, such as seizures or asthma.

3.4 End-to-end Safety Service

There are many things to consider when talking about children’s safety and well-being in day-care centers and schools, especially if children travel to school independently. Parents worry about a child’s safety, particularly in an urban environment, where the level of outdoor risk is perceived as particularly high. New technology has already made it possible to monitor children, most notably through their cellphones and other small GPS-based devices. Our research work and technical implementation provide solutions to some of these issues regarding: children’s outdoor activities, children going outside the nursery or school premises (on trips, sports lessons, arriving to school or nursery etc.), children’s disappearances from the nursery or school, and guardians fetching the children from the nursery or school. The overall end-to-end safety service framework consists of different levels for collecting and providing the sensor data to be utilized by the end-users’ safety applications and services. The goals of the safety service solution were defined as:

- provide continuous and real-time monitoring of children’s movements
- perform complex reasoning based on different data sources

- provide alerts in the case of an emergency

The safety service application provides a GUI (Graphical User Interface) for teachers and parents, through which they can monitor the child's last known locations as seen in Fig. 4. Teachers and parents have a separate level of access to the child's location information, where a teacher is only shown whether the child has arrived or left the school area. Teachers are also shown child's absence notifications left by the parents for their children, whereby a notification removed an alert of a missing pupil from the teacher's view on the GUI. Parents have finer access to the location data, and they are shown the same data as teachers, but in addition, the parents are shown their child's current and previous locations on a map. In the case of school children, the application also uses the home location information to determine if a child is at a classmate's house and shows the parents the name of the classmate the pupil is visiting. This, however, requires that the classmate's parents have enabled their home's location to be publicly available to other parents.
Technical design of the safety application consists of a role (teacher, parent) separated GUI and server software that provides an interface for the GUI to read the different information, such as child's class information, school or day-care center and home location, GPS outdoor location data, and RSSI/RFID based indoor location data. Server software also provides an interface for the location devices to store the child's location. The GUI is an HTML5 web application run in a web browser, and the server software is a Java–based web application run on a Tomcat web application server. The application data is according to a specific semantic model that is designed for the school domain, and the data is stored semantically in a Virtuoso RDF (Resource Description Framework) database.

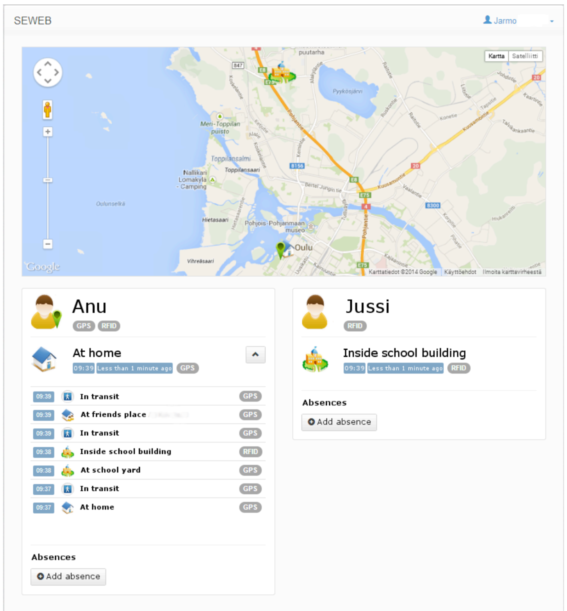

Fig. 4. Safety service for children GUI

4. Gateway Implementation

The system gateways are implemented using Intel Galileo [17] and Raspberry Pi [31], which are small computers suitable for covering indoor and outdoor spaces, because of both their size and cost. The Raspberry Pi is shown in Fig. 5. The gateway provides the basic set of functions to work as an Internet of Things (IoT) gateway to deliver the data to our safety service working on the Internet. In the Raspberry, we run a Raspbian operating system, which is a Debian-based Linux distribution optimized for Raspberry Pi.

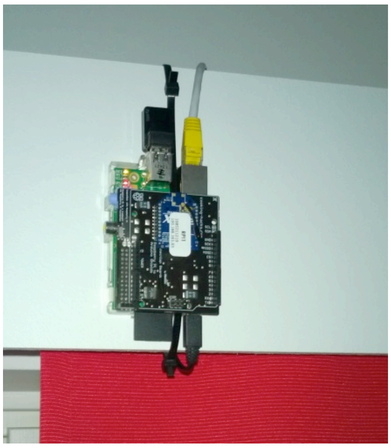

Fig. 5. Raspberry Pi sensor gateway

We programmed the gateway using C++, to be consistent with the code written for the vests. Raspberry Pi has an Ethernet port to connect to a local area network, and an XBee radio shield to communicate with the vests. Detecting whether the child's location is inside the allowed indoor or outdoor area can be based on the XBee radio range covered by the gateway(s). The location is measured using the RSSI values, utilizing an algorithm that is based on the weighted centroid localization method [6]. The location is weighted towards the gateway(s) that receive the best RSSI, and thus the algorithm robustly gives us a rough estimation of the area where the vest is. Experiments show that the well-known RSSI-based indoor localization algorithms can have errors of several meters [37], [25]. This is, however, sufficient for our purposes. More details about the localization algorithms are presented in next Section.
In order to support special use cases, when the mobility and portability of the gateway is required but the battery lifetime does not need to be very long, such as during sport lessons and day-care center or school trips, other radio modules with a wider range (GSM, 3G, BLE (Bluetooth Low Energy), and Wi-Fi) can also be used in gateway(s) and the vests. Besides having the capabilities of lightweight computers, Raspberry Pi and Intel Galileo can also host multiple sensors and implement intelligent reasoning algorithms for decision-making.

4.1 Localization Algorithms

Localization can be done by measuring RSSI from multiple gateways equipped with a radio module. Standards like Bluetooth, RFID, Zigbee and Wi-Fi are commonly used alternatives for localization [25]. Our system utilizes XBee 802.15.4 radios to transmit and receive sensor data, so additional hardware was not required for localization. The vest is set to broadcast sensor data in regular intervals, and the gateways record the RSSI from the incoming messages. RSSI values are sent to a remote server where the location is calculated. The limitation of RSSI based localization is the difficulty to reliably estimate distances just based on the RSSI [5]. However, some encouraging results exist where distance and localization errors have been reduced to few meters by improving the distance estimation calculation and the localization algorithms [37], [15], [2]. When the distances to three or more gateways are known, the location can be calculated using algorithms, such as trilateration and leastsquares algorithm [25]. On the other hand, Ultra Wideband Localization (UWB) systems using Time Of Arrival (TOA) and time difference of arrival (TDOA), have shown to narrow the error to only few centimeters [32], [36]. The problems of UWB systems are the additional complexity and cost. The vest is also equipped with a GPS module, which cannot reliably be used for indoor localization due to walls and structures that weaken the signal. In a small outdoor area, RSSI based localization systems may even outperform GPS. In [24] it was shown that commercial GPS devices have localization errors of around 8-15 meters for the first fix in an open environment and the time it takes to get a fix is around 30 seconds. There is no such noticeable first fix lag involved with RSSI based localization. As mentioned before, RSSI based localization uses algorithms that rely on distance estimation, but the location can also be determined symbolically by using proximity method [25]. Symbolic location is a known area, e.g., a specific room in a building, where the gateways can be placed in different rooms or areas. Hence, the vest is most likely located in the area that receives the best signal strength. For RSSI based localization we decided to use a weighted centroid localization algorithm [6]. Its performance depends on the weights that are inversely proportional to the distance to some power g. With larger weights i.e., smaller values of g, the position is moved more towards the gateway that receives the best signal strength. Therefore, with larger weights, the algorithm behaves like a proximity based algorithm providing a robust way to roughly localize vests to different areas and scaling well with multiple gateways.

5. Conclusions and Future Work

This work presented wearable safety vests with GPS, an accelerometer and temperature sensors to be used in day-care centers and schools. Our safety vest prototypes were built from “off-the-shelf” small computing platforms, which made it possible to build and test our own system. Hence, the utilized wearable technologies are still gaining increased popularity, and it can be expected that these technology environments will be improved in the coming years. However, a considerable number of technical implementations are still required to make a large-scale end-to-end sensor system functional.

The basic functionalities of the vest have been tested but more concrete large scale real-time measurements and analysis will be done as a future study. The usability of the safety and location services has been piloted in a Finnish primary school [13] with good results. The technicalities of the vest do not restrict adding other sensors as well, or having other end users besides children. The current vest prototype is designed to mainly provide safety, behavior and activity-related information, but as a future work, the vest could be made more appealing from the children's point of view and include some gaming and socializing applications. We are also aiming for more intelligent reasoning and context-awareness using the input from many sensors to assist in decision making. The situation-aware application will be based on the earlier work on run-time context management with the context ontology dedicated for the smart applications [29]. The data gathered from one sensor is usually not enough to draw conclusions, but if we are able to do the reasoning based on multi-sensor data, the applications and services around the system will be more valuable.

Acknowledgments

The work was primarily done in a Tekes-funded SEWEB (Sensors and Social Web) project. The authors would like to thank VTT and Tekes for their financial support, and also Mr. Juhani Laitakari from VTT for the application part implementation.

References

[1] Adafruit flora, url: http://www.adafruit.com/flora, Accessed at 29 October 2014.

[2] Adewumi O, Djouani K, and Kurien A. RSSI based indoor and outdoor distance estimation for localization in WSN. *Ind. Technol. ICIT 2013*, pp. 1534–1539.

[3] Aminian K, and Najafi B. Capturing human motion using body-fixed sensors: Outdoor measurement and clinical applications. *Comput Animat. Virtual Worlds Conf. 2004*, vol. 15, pp. 79–94.

[4] Basak A. et al. KiMS: Kids’ Health Monitoring System at day-care centers using wearable sensors and vocabulary-based acoustic signal processing. *International conference on e-Health Networking Applications and Services (Healthcom)*, 2011, pp. 1–8.

[5] Benkic K, Malajner M, Planinsic P, and Cucej Z. Using RSSI value for distance estimation in wireless sensor networks based on Zigbee. *Syst. Signals Image Process. 2008 IWSSIP 2008*, pp. 303–306.

[6] Blumenthal J, Grossmann R, Golatowski F, and Timmermann D. Weighted Centroid Localization in Zigbee-based Sensor Networks. *Proc. IEEE Int. Symp. Intell. Signal Process. 2007*, pp. 1–6.

[7] Boughorbel S. et al. Child-activity recognition from multi-sensor data. In *Proceedings of the 7th International Conference on Methods and Techniques in Behavioral Research*, 2010, p. 38. http://dx.doi.org/10.1145/1931344.1931382

[8] Bröring A et al. Sensor bus: an intermediary layer for linking geosensors and the sensor web. In *Proceedings of the 1st International Conference and Exhibition on Computing for Geospacial Research and Application*, 2010. http://dx.doi.org/10.1145/1823854.1823870

[9] Bröring A. et al. New Generation Sensor Web Enablement, in *Journal of Sensors*, 2011, vol. 11.

[10] Buechley L, Eisenberg M, Catchen J, and Crockett A. Using computational textiles to investigate engagement, aesthetics, and diversity in computer science education. *Proc. SIGCHI Conf. Hum. Factors Comput. Syst. 2008*, pp. 423–432.

[11] Digi International http://www.digi.com/, Accessed at 29 October 2014.

[12] Ervasti M, Kinnula M, and Isomursu M. User experiences with mobile supervision of school attendance. *Int J Adv Life Sci 2, 2010*, no. 1 and 2, pp. 29–41.

[13] Ervasti M, Laitakari J, and Hillukkala M. A Situation-Aware Safety Service for Schoolchildren – User Experience Findings. *CHI2015 ACM Press*.

[14] Filip a wearable smart locator and phone for kids. http://www.myfilip.com, Accessed at 29 October 2014.

[15] Goldoni E, Savioli A, Risi M, and Gamba P. Experimental analysis of RSSI-based indoor localization with IEEE 802.15.4. *Wirel. Conf. EW 2010 Eur.*, pp. 71–77.

[16] Hamanaka M, Murakami Y, Usami A, Miura Y, and Lee S. System for detecting kindergartners potential emergency situations. *World Multi-Conf. Syst. Cybern. Inform. 2010*, pp. 296–301.

[17] Intel Galileo,http://www.intel.com/content/www/us/en/do it-yourself/galileo-maker-quark-board.html, Accessed at 29 October 2014.

[18] Jang H, Choe SP, Hwang I, Hwang C, and Nachman L. RubberBand augmenting teachers awareness of spatially isolated children on kindergarten field trips. *Proc. 14th Int. Conf. Ubiquitous Comput. 2012*.

[19] Jutila M, Rivas H, Karhula P, and Pantsar-Syväniemi S. Implementation of a Wearable Sensor Vest for the Safety and Well-being of Children. *5th Int. Conf. Ambient Syst. Netw. Technol. ANT-2014 & 4th Int. Conf. Sustain. Energy Inf. Technol. SEIT-2014*, vol. 32, pp. 888–893.

[20] Kim J, Yoo M, and Kim K. A privacy-preserving kid's safety care service based on sensor network in u-city. *Proc. 2010 Symp. Cryptogr. Inf. Secur.*, vol. 22, p. 2010.

[21] Kim J, Kim K, Park J, and Shon T, A scalable and privacy-preserving child-care and safety service in a ubiquitous computing environment. *Advanced Theory and Practice for Cryptography and Future Security, 2012*, vol. 55, no. 1–2, pp. 45–57.

[22] Klurfeld M. California school uses rfid tags to track location of preschoolers.

[23] Lee S, Lee J, Sohn A, Usami M, and Hamanaka M. Development of wearable device by kids friendly design for kids safety. *Human-Computer Interaction, 2010*, pp. 80–85.

[24] Lehtinen M, Happonen A, and Ikonen J. Accuracy and time to first fix using consumer-grade GPS receivers. *Softw. Telecommun. Comput. Netw. 2008*, pp. 334–340.

[25] Liu H, Darabi H, Banerjee P, and Liu J. Survey of Wireless Indoor Positioning Techniques and Systems. *IEEE Transactions on Systems, Man, and Cybernetics, Part C: Applications and Reviews*, vol. 37, no. 6, pp. 1067–1080. http://dx.doi.org/10.1109/TSMCC.2007.905750

[26] Ma J, Yang L, Abduhan B, Huang R, Barolli L, and Takizawa M. Towards a smart world and ubiquitous intelligence: a walkthrough from smart things to smart hyperspaces and UbicKids. *International Journal of Pervasive Computing and Communications, 2005*, vol. 1, pp. 53–68. http://dx.doi.org/10.1108/17427370580000113

[27] Mustafa S and Chua HN. Dynamic Service Composition for Telecommunication Services and Its Challenges. *Journal of Ubiquitous Systems & Pervasive Networks*, vol. 5 (1), pp. 17-24, 2014.

[28] Northstart: Take me home, http://www.northstar.ws, Accessed at 29 October 2014.

[29] Pantsar-Syväniemi, "Reusable, semantic, and context-aware micro-architecture. Approach to managing interoperability and dynamics in smart spaces," University of Oulu, 2013.

[30] Q sensor device, http://www.qsensortech.com, Accessed at 29 October 2014.

[31] Raspberry pi foundation, url: http://www.raspberrypi.org, Accessed at 29 October 2014.

[32] Silva B, Pang Z, Akerberg J, Neander J, and Hancke G. Experimental study of UWB-based high precision localization for industrial applications. *IEEE Ultra-WideBand ICUWB 2014*, pp. 280–285.

[33] Strohrmann C, Seiter J, and Tröster G. Feedback Provision on Running Technique with a Smartphone. *Journal of Ubiquitous Systems & Pervasive Networks*. vol. 5, no. 1, pp. 25-31, 2014.

[34] Takata K, Shina Y, Komuro H, Tanaka M, Ide M, and Ma J. Designing a context-aware system to detect dangerous situations in school routes for kids outdoor safety care. *Embedded and Ubiquitous Computing, 2005*, pp. 1016–1025.

[35] Takata K, Ma J, and Abduhan B. A context based architecture for ubiquitous kids safety care using space-oriented model. *11th Int. Conf. Parallel Distrib. Syst. 2005*, vol. 1, pp. 384–390.

[36] Wang T, Chen X, Ge N, and Pei Y. Error analysis and experimental study on indoor UWB TDoA localization with reference tag. *Communications (APCC), 2013*, pp. 505–508.

[37] Zanca G, Zorzi F, Zanella A, and Zorzi M. Experimental comparison of RSSI-based localization algorithms for indoor wireless sensor networks. *Proc. Workshop Real-World Wirel. Sens. Netw. 2008*, pp. 1–5.

[38] 52º North Initiative for Geospatial Open Source Software, URL: http://52north.org.

[39] 52º North, SOS implementation, URL: http://52north.org/communities/sensorweb/sos/download.html.

[40] 52º North Sensor bus implementation, URL: https://svn.52north.org/svn/swe/incubation/SensorBus/trunk/52NSensorbus.