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Wearable and mobile sensors connected to social media in human well-being applications

Matti Kinnunen [a,*], Salman Qayyum Mian [b], Harri Oinas-Kukkonen [b], Jukka Riekki [c], Mirjami Jutila [d], Mari Ervasti [d], Petri Ahokangas [e], Esko Alasaarela [a]

[a] Department of Electrical Engineering, University of Oulu, Finland
[b] Department of Information Processing Science, University of Oulu, Finland
[c] Department of Computer Science and Engineering, University of Oulu, Finland
[d] VTT, Technical Research Centre of Finland, Oulu, Finland
[e] Oulu Business School, University of Oulu, Finland

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ABSTRACT

Safety of children and marginalization of youth are increasing problems in our modern society. Developing technologies, however, offer more possibilities for building safety solutions for children and teenagers. This paper describes a new concept of using sensors to monitor human behavior in combination with data processing and information transfer via different communication channels as well as different types of support the concept makes available. The concept utilizes the web and social media to create services and new business centered around different applications designed to support child safety in challenging situations and to prevent the marginalization of young people. This conceptual work involves different sub-concepts in the areas of information flow and connections, potential services and business potential. Some application areas will be introduced and discussed as specific cases demonstrating the features of the developed concept.

1. Introduction

Human well-being includes several dimensions, including physical, mental and social well-being. Similarly, human ill-being can be divided into many categories. Although well-being and ill-being are not complete opposites, lack of well-being may very well lead to ill-being. In recent years, increasing attention has been paid to personalized health support systems (Free et al., 2013; Matthews et al., 2008; El-Gayar et al., 2013) and preventive measures to control such diseases as diabetes. In terms of overall well-being, it is important to support actions geared toward promoting health, well-being and motivation at the individual level (Kay et al., 2011).

Nowadays, individualism is gradually increasing, emphasizing individuals' right to satisfy their personal needs. At the same time, collectivism is being promoted and new solutions for effective communication are being developed but, in fact, interaction between people is becoming more superficial, to the point that personal peer relations may even be weaker than before (Oinas-Kukkonen and Oinas-Kukkonen, 2013). One reason for this development is ever-hardening competition between people, bred by the increasing inequality created by a business-minded lifestyle. This is particularly true of

* Corresponding author at: Optoelectronics and Measurement Techniques Laboratory, P.O. BOX 4500, FI-90014 University of Oulu, Finland.
E-mail addresses: matti.kinnunen@ee.oulu.fi (M. Kinnunen), Salman.Mian@oulu.fi (S.Q. Mian), harri.oinas-kukkonen@oulu.fi (H. Oinas-Kukkonen), jpr@ee.oulu.fi (J. Riekki), Mirjami.Jutila@vtt.fi (M. Jutila), Mari.Ervasti@vtt.fi (M. Ervasti), petri.ahokangas@oulu.fi (P. Ahokangas), esko.alasaarela@ee.oulu.fi (E. Alasaarela).

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Asian cultures (Ogihara and Uchida, 2014). However, other studies show that individualism can in some cases also bring satisfaction to life (Veenhoven, 1999).

Children's growth environment strongly affects their well-being and their possibilities to grow into happy adults (Roysamb et al., 2003). Discarded children become tomorrow's marginalized youth and lost adults. How could this fatal course of development be stopped? How could signals of ill-being in children and young people at large be indicated and measured? How could these signals be used to break the spiral of exclusion? Could social media be harnessed to provide help, when sensors monitoring an individual's physiological and psychological signals indicate ill-being?

Wearable and mobile sensors enable monitoring human behavior in different conditions (Kay et al., 2011; Hao and Foster, 2008). Low power consumption and robust sensor design support consumer applications that could be applied to recognize challenging situations where children and youngsters need help (Czeskis et al., 2010). Human behavior can also be monitored and made more visible using portable devices containing a range of embedded sensors (Kay et al., 2011; ScienceDaily, 2014; Dey et al., 2014). Connecting sensors to social media systems is increasing rapidly, especially among fitness people. A number of activity buttons and wristbands (e.g., Fitbit Flex, Jawbone Up, Polar Loop, Withings Pulse) can be connected to different types of media to transmit performance data to friends. According to UNICEF, this offers a boost to developing technology for safety applications targeted at children (Mattila, 2011).

Supporting children to grow into happy adults benefits not only children and young people, it also increases the well-being of their families and friends, and saves the resources of society. It has been calculated that the societal cost of each marginalized youngster is at least one million euros. The most central and important objective, however, is that children should not fear being alone and young people should not be excluded from society. This paper introduces a concept based on monitoring human behavior using sensors with social media connectivity to distribute data and provide help to people in challenging situations.

2. Research methods

This study applies the following research methods: (1) literary studies from technical and scientific databases, company web pages and blogs, (2) queries to experts on the theme, (3) internal brain storming of the research group, (4) writing and analyzing the use of case stories, and (5) building and experimenting service concepts with practical, real-life pilots with potential end-users in a primary school and nursery environment.

3. Concept creation

A concept is needed to define what is measured and how, what is processed from the data and how to deliver feedback to users. In addition, it is important to consider the users' point of view: why would they need help, what would motivate them to seek help and what form should this help take.

3.1. What is measured, processed and how?

Technologies used to identify and measure relevant signals are:

(1) Sensors, microphones, cameras and processing capacity of smartphones.
(2) Wearable sensors, such as wristbands, necklaces, chest-belts, sensor clothing, etc.
(3) Ambient sensors, such as those available as smart home accessories.

Types of data measured and collected by sensors:

(1) Activity data.
(2) Location data.
(3) Voice data.
(4) Health-related data.
(5) Well-being data.

Technologies used to collect, process and share/display data are:

(1) Smartphone apps.
(2) Cloud computing services.
(3) Social media solutions, such as Facebook.
(4) Wearable safety devices (utilizing GPS and RFID technologies).

Phenomena to identify, measure and categorize are:

(1) Changes in stress level.
(2) Emotional state changes (fear, anger, sadness, etc.).

(3) Fast and slow changes in mood.
(4) Changes in physical activity level and modality.
(5) Detailed location information (both indoors and outdoors).

The reason for selecting these phenomena is grounded on the need to analyze multisensory data and identify parameters that indicate ill-being symptoms for diagnosing physical, mental or social ill-being status (Hao and Foster, 2008; Wijsman et al., 2011; Ferdinando et al., 2014). For example, a rapid change in emotional status following a slow gradual decrease in physical activity may reveal an important change in a person's ill-being status.

3.2. The SEWEB concept

SEWEB, the name of the concept, comes from the abbreviation of an existing project "Sensors and Social Web". At its core lie innovative sensor and social media solutions, which help to identify feelings of insecurity in children and exclude threats to young people. It is designed to provide family and friends with means and channels to provide support and help in difficult situations. New types of sensors, location information applications and game-like innovations in social media are under strong development and will produce a stream of innovations both for well-being and ill-being.

As shown in Fig. 1, the concept relies on measured data that is analyzed, and feedback is sent to the user. Different feedback loops are an essential part of the concept. Feedback can be experienced as direct support, support via family or support via friends through social media. Depending on measurement results, a range of customized messages can be sent to different user groups, such as family members, friends or other trusted individuals. The user can also send direct requests to trusted people. Estimating the level of threat is another important consideration for deciding on the most appropriate form of support. In addition, the concept includes the possibility of providing automated messaging and service solutions, allowing parents or other trusted individuals to obtain information about their children who, based on location and other sensor data, find themselves in a challenging situation.

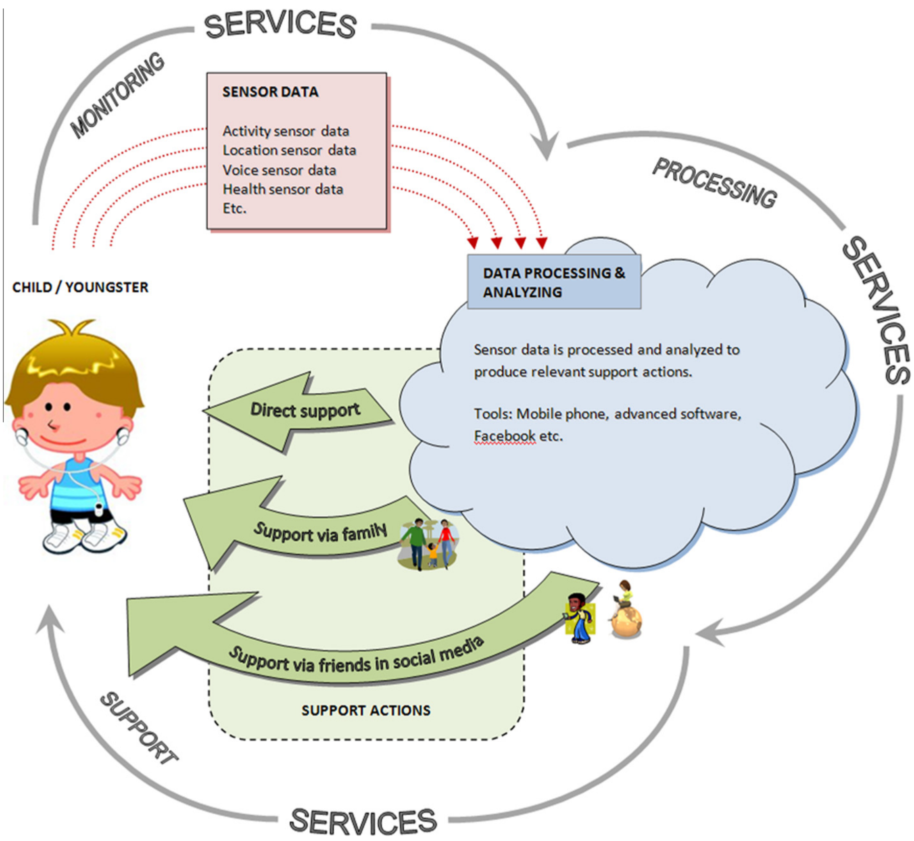

Fig. 1. SEWEB concept: monitoring services produce activity, location, voice and health-related data; processing services analyze these data and generate reports and actions, which are fed back to the target person directly, via family and peer members or via social media by support services.

3.3. SEWEB sub-concepts

To effectively operationalise the SEWEB concept (Fig. 1), sub-concepts were defined to describe socially challenging situations, which the SEWEB solution would be applicable to. The following sub-concepts, discussed by Mian et al. (2015), were identified: (1) personal safety network, (2) notifications, (3) challenging situations, (4) context and sensor data, and (5) communication channel.

3.3.1. Personal safety network

Personal safety network (PSN) represents the network connections a user, such as a pupil, wants to be in touch with in case of emergency or when encountering socially challenging situations. An important aspect is that the user can restrict the group or individuals who have access to the network. PSNs can be defined as dynamic logical groups based, for example, on the severity of the challenging situation, friends/family/teachers or primary/secondary contacts, etc. (Fig. 2). Communication can be initiated either automatically or manually by the user. In addition, safety network connections can be static or dynamic, based on the user's current location. The need for different types of contact is evident and depends on the type of challenging situation, as well as several other aspects, including time (teachers may not always be available) and location (teachers are not to be alerted, for example, when the pupil is on the way to home after a school day). Immediate contact person is defined as an individual who must to be contacted when the user's life is in danger, as when low blood glucose levels are recorded for a diabetic child. Defining a correct contact person requires understanding the context (e.g., when a child breaks an arm in school, the first contact should be the school nurse rather than the parents).

3.3.2. Notifications

Notification refers to the act of informing a target person, i.e., providing them with meaningful information. Notifications can be either user-initiated or sensor-initiated. User-initiated notifications can be predefined or created on the spot. Also system-initiated notifications can be of both types; thus, a dangerously high level of air pollution can trigger a notification automatically, based on sensor readings, and inform the user of the danger. In the case of a child with respiratory problems, a predefined notification can be triggered by sensor data and inform both the child and the parents. Sensor-triggered notifications should include self-notifications, which alert the user to take control of the issue at hand. To eliminate the risk of the system to draw a wrong conclusion, it would be essential to know relevant differences between different individuals. A specific stressful situation, may have severe consequences for one person, while another individual only requires self-notification, with no external help. For that reason, notification targets should not only include outside contacts, but also the person concerned. For example, if a trend is observable in time and the system recognizes that stress is building up, it can prompt the person to pay more attention to the environment.

3.3.3. Challenging situations

A challenging situation could be defined as a situation where one experiences a physical or mental problem and would like to receive help from trusted people. A key question here is who determines and decides that a particular situation is challenging.

Fig. 2. Dynamic safety network.

3.3.4. Context and sensor data

Sensors also acquire data from the environment, allowing the operational context of the sensors and the user to be considered. Context and sensors play a key role not only in socially challenging situations, but also serve to justify their application to the SEWEB concept. This component centers mainly around monitoring the user and their environment. By using the term 'context', we emphasize that interpretation of results is not limited to sensor measurements, but also includes making sense of them. For example, a heart rate sensor makes measurements in terms of bpm (heartbeats per minute); however, heart rate can vary according to the physical status of an individual. Thus, by recording a heart rate of 90 bpm, for example, we have valid sensor data, but for an individual with an average heart rate of 76 bpm, that is a bit fast. Then again, if that individual is on a routine morning run, this reading should not be a cause for alarm, since the heart rate goes up during physical exercise. Therefore, it is necessary to know the context in which a sensor measurement is recorded.

3.3.5. Communication channel

Communication channel is seen as a part of notifications. It is dependent on an individual's personal safety network. Communication can take different forms, and not all people included in an individual's network are connected in the same way. Communication should support different modalities, such as audio, video and text, selected on the basis of the situation at hand and the severity of the notification. Obviously, users should be able to filter and interpret notifications according to their needs. One of the communication channels could be a portal that enables friends and relatives to see a person's "status", i.e., a timeline or a snapshot of what the person has been doing. One important aspect should be power consumption monitoring (has grandpa remembered to charge his safety device?) to avoid situations in which a person goes "missing", because a device has shut down due to low battery, for example.

When brainstorming on automatic intelligent messaging, the dual connection concept (Mian et al., in preparation) was at the core of our SEWEB sessions.

Conventional information flow between a sensor and the social web is a one-way street, based on extraction of information or placement. Sensor data is shared on the social web on the user's initiative. One-way flow is useful in many situations, but more advanced functionality can be realized with bidirectional flow. Here, a sensor automatically invokes the social web to obtain relevant information that can influence the user. The social web can also take the initiator role and provide useful information for the sensor to act on. Fig. 3 shows a dual connection between the social web and sensors.

3.4. SEWEB service concept

The service concept describes how the concept can be utilized, why help is needed, what motivates individuals to seek help and how they want to be helped. To that end, we defined several challenging situations where the concept could be utilized. These situations included traffic safety, encountering strangers, witnessing an accident, low self-esteem, shoplifting and visiting a friend.

As an example, the low self-esteem scenario introduces several challenges related to peer pressure in the school environment (Fig. 4). In addition to the physical environment, peer pressure spreads online as teens use social networks extensively. This pressure originates from continuous competitiveness at school: pupils are being observed and evaluated by others (online profiles are compared to those of others, etc.). As a result of this pressure, some pupils experience such adverse emotions as stress and low self-esteem.

As another example of a possible service, we describe a service concept designed to meet the growing need to ensure the safety of children. A situation-aware safety service for schoolchildren was created for enhancing and securing children's independent mobility, especially during home-school transition (Fig. 5). This safety service concept is based on tracking pupils' whereabouts based on "safety gadgets" (GPS devices, smartphone apps, indoor wristbands, safety vests and RFID tags). By combining different tracking methods, the position of children can be followed during the school day, from home to school and back. Information related to the location of children is shown to their parents and teachers via a separate dedicated GUI (Graphical User Interface) (Jutila et al., 2015).

3.5. Business concept

A business model is a conceptual tool that defines how a company does business and what strategic goals it strives to achieve. Essentially, the business model can be considered as a framework that helps to design and form necessary business structures and systems to exploit business opportunities (Hacklin and Wallnöfer, 2012). It is typically formed through four questions: what, how, why and where the company is acting.

Key elements of this business model concept, built around a business opportunity, include the following:

- What? Offering, value proposition, customer segments and differentiation.
- How? Key operations, basis of advantage, mode of delivery, selling and marketing.
- Why? Base of pricing, way of charging, cost elements and cost drivers.
- Where? Location of activities/items, internally or externally of the company.

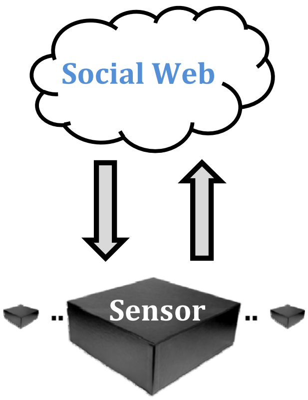

Fig. 3. Dual connection.

These questions were answered for the child safety service by applying the business model wheel (Fig. 6) (Ahokangas et al., 2014) to the SEWEB concept. In defining the value net, children were regarded as end users. However, several alternatives were considered as customers, including parents, school or community. In the final analysis, parents were perceived as customers.

3.6. Child safety service pilot in the school environment

A child safety service application for monitoring the safety of pupils was designed and developed for use in the elementary school environment (for a more detailed description of the participatory co-design process, see Pantsar-Syväniemi et al., 2014). Findings gained during the design process confirmed the need for remote monitoring, especially on school journeys, as these raised safety concerns both among schoolchildren and their caretakers. The youngest schoolchildren, aged 7–10, appeared as most suitable users of the safety service, since older children already use cell phones actively, know about safe routes and understand possible risks. They also know how to manipulate and cheat the system. Since age turned out to be a critical factor for acceptance of the system, parents and teachers agreed that the service was most appropriate for the youngest schoolchildren. They also pointed out that, as children easily forget or lose their belongings, the "safety gadgets" should be easy to use and unobtrusive to carry along.

The application is built around information provided by (1) *GPS devices* ("safety sticks") and (2) *RFID tags* (attached on key chains) carried by the pupils. Both devices are used to determine the pupils' locations in a complementary fashion. Being more reliable outdoors, GPS is used to pinpoint outdoor locations, whereas RFID tag readings are used indoors, where GPS may be inaccurate. RFID readings provide indoor location data in the school building via RFID reader devices located strategically at congestion points, such as narrow corridors and doorways, to minimize the chance of a misread. In this way, an RFID reading registered by a certain reader places the pupil in that device's location and can be used to determine, whether the pupil has entered or left the space.

The pupils' own smartphones were utilized for collecting information about their movements between their home and school through a (3) *smartphone application* provided by a local telecom operator. Furthermore, (4) *safety indoor wristbands*

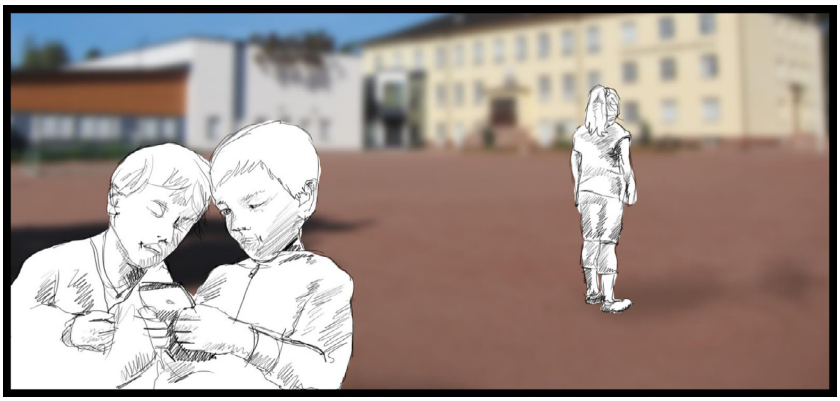

Fig. 4. Low self-esteem scenario.

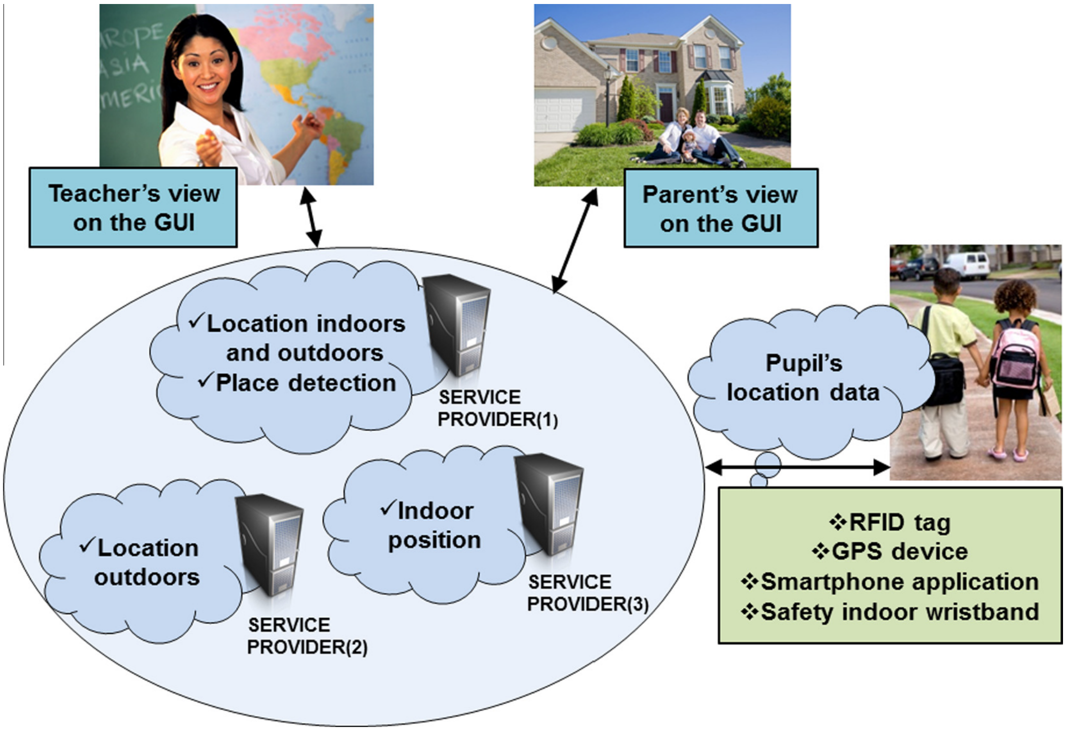

Fig. 5. An overview of the safety service system (© Springer-Verlag London 2015, Jutila et al., 2015, with kind permission from Springer Science and Business Media).

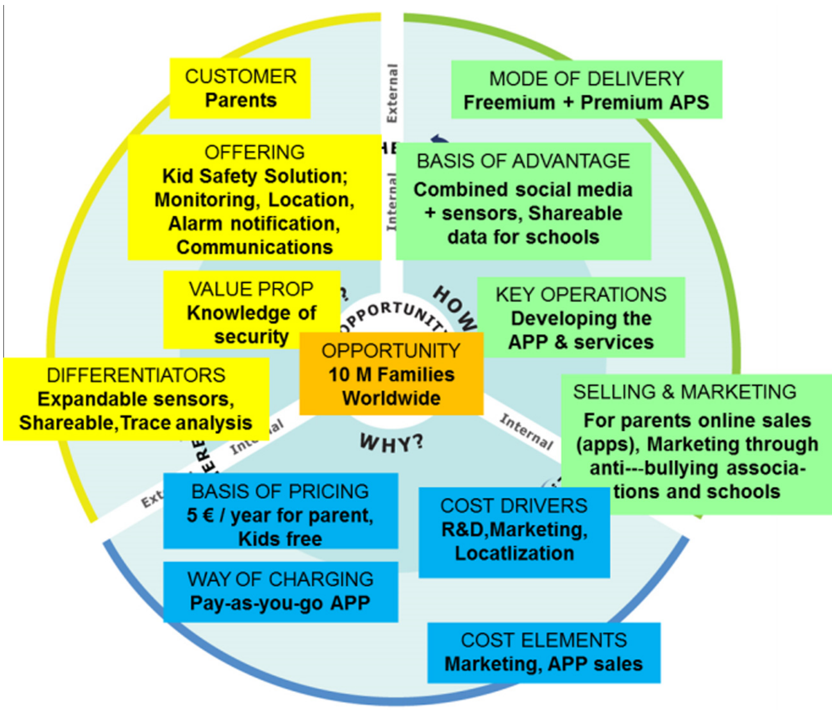

Fig. 6. SEWEB business model.

were given to pupils diagnosed with diabetes. This service offered indoor position tracking on school premises, collecting information of the pupil's location inside the school building. These safety wristbands had an alarm button that could pressed when in need of attention, alerting the school supervisor (the alarm was sent to the supervisor's mobile phone). The application provides a GUI (Graphical User Interface) to teachers and parents, through which they can monitor the child's latest known locations. Teachers and parents have a separate level of access to this location information, such that teachers are only shown whether the pupil has arrived or left the school area (based on GPS), and whether his/her RFID tag is registered in a certain space (corridor, classroom, etc.) within the school building. Teachers are also shown pupil absence notifications, reported by parents; a notification removes a missing pupil alert from the teacher's view on the GUI. Parents have wider access to location data and, in addition to data shown to teachers, they can also view their children's current and previous locations on a map. Furthermore, the application uses the pupils' home location to determine, if they are at a classmate's house and shows the parents the name of the classmate. This, however, requires that the classmate's parents have enabled their home location to be publicly available to other parents.

In spring 2014, the safety application was tested in a three-month field trial at a local primary school in northern Finland. The trial included 59 pupils between the ages of 7 and 10 from 8 different classes, as well as 8 class teachers and 57 parents. Not all pupils in the selected classes participated in the trial, as their parents did not give permission. Willingness to participate had been established in advance through a separate form delivered to the pupils' homes. On the same form, parents could also indicate which of the four safety service components they wished to use. One of the main findings was that the concept of technological monitoring offers a practical method of increasing child safety. In fact, children were eager to adopt this new technology to provide information to the application used by their parents or teachers. Older children, however, were considerably less enthusiastic to be supervised in this manner. Age is thus an important consideration, when selecting the most suitable target group for a future application (Jutila et al., 2015).

3.7. Safety vest prototype

As a part of the SEWEB concept, a prototype wearable sensor vest was built for improving the safety and well-being of children in nurseries, day care centers and primary schools. The vest gathers and provides real-time information about the presence or absence of children from specific outdoor or indoor areas, based on GPS and the RSSI (Received Signal Strength Indication) signal strength of the used radio module (ZigBee 802.15.4. and Wi-Fi tested). RSSI-based location calculation uses a weighted centroid localization algorithm (Blumenthal et al., 2007). As location is weighted towards the gateway(s) that receive(s) the best RSSI, the algorithm gives us a rough estimate of the area where the vest is. In addition, the vest gathers additional sensor information about the overall well-being, behavior and activity of the wearer through temperature and accelerometer sensors. Our safety vest implementation provides a solution to issues such as children's outdoor activities, going outside the nursery/school premises (trips, sports, arriving in the school area/building, etc.), children going missing and parents fetching their children from the nursery/school. For more detailed information about the vest implementation, see our recent publications (Jutila et al., 2014, 2015).

The system design utilizes available "off-the-shelf" wearable sensor components from Arduino LilyPad (Buechley et al., 2008) and Adafruit Flora (Adafruit flora). Of the radio components provided for the platforms, ZigBee 802.15.4 and Wi-Fi were tested. Fig. 7 illustrates the prototype vest, with the components sewn on a separate transferable piece of fabric (the yellow part) for testing purposes. Overall system architecture also requires a sensor gateway(s) for connectivity and

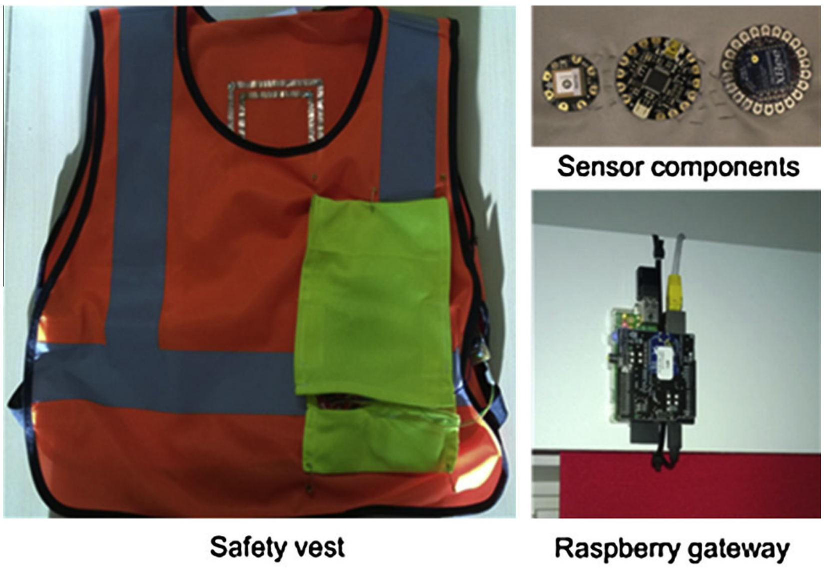

Fig. 7. Sensor vest, some of the components, and a gateway (© Springer-Verlag London 2015, Jutila et al., 2015, with kind permission from Springer Science and Business Media).

interfacing with safety service applications. In our work, we have utilized microcomputers: Intel's Galileo (Intel Galileo) and Raspberry Pi (Raspberry) (shown in Fig. 7), which are suitable for our purposes due to their small size and cost. A gateway of this type provides a basic set of functionalities to serve as an Internet of Things (IoT) gateway to deliver recorded data to cloud services and further to our safety service applications.

4. Discussion

Having a wide application area, the proposed SEWEB concept allows using various sensors to measure parameters of human physiology, such as continuous monitoring of ECG, heartbeat rate and blood pressure, or *in vitro* diagnostics using samples from blood or saliva. Different parameters can then be used to calculate indicators related to ill-being or well-being (Ferdinando et al., 2014). By combining physiological data with activity and environmental data, we may discover different changes in emotional state as well as threats encountered by children. This information can then be combined with location data. Harnessing the social web using one and two-directional data transfer enables the concept to offer a new basis for providing immediate help to people in distressing situations.

There is plenty of potential for novel service solutions and business cases based on utilizing sensors and the social web. However, if a solution for the remote monitoring of child behavior and location requires tracking, legislation may hinder implementation in many countries. On the other hand, if the solution took the form of a mobile application, available on the app market, successful marketing and attracting a large user base may also prove a challenge. We assume that technological challenges are smaller than those related to reaching customers and gaining a critical mass of users. Further challenges include privacy and raising responsible citizens.

The aim of the SEWEB business model is to provide a description of actions representing the core aspects of a business utilizing the SEWEB concept. Many elements at the concept level of the SEWEB project were simplified, as real-life complexities were not sufficiently well known and could not be fully taken into consideration. On the other hand, business model analysis lends itself particularly well to visioning, because it defines company logic at the strategic level and does not even attempt to focus on business process design.

The described SEWEB concept can also be expanded to different application areas, for example, to school bullying (Ye et al., 2014a,b) or to other user groups besides children, such as older people.

5. Conclusion

A concept based on a combination of sensors and the social web has been established in the course of this work. Together with its sub-concepts, it defines a framework for and specific aspects of communication in several application areas, in which sensors are used to track human behavior and measure the human physiological status. The thus gathered information is then shared via social media. Testing and evaluation of the concept was conducted using a schoolchildren's safety service application, and a related business model was created to discuss aspects linked to the concept's commercialization prospects.

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