STATE OF THE ART

AND THE ASSESSMENT OF INTERACTION, SENSING DATA MANAGEMENT, AND SERVICE TECHNOLOGIES FOR WEARABLE APPLICATIONS

DELIVERABLE D1.4

by
NXP Semiconductors Belgium N.V.

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SUMMARY

This document (deliverable D1.4) describes the state-of-the-art (baseline) for the CareWare technologies and its system(s). The deliverable starts with a recapitulation of the defined use cases – in order to set the technology/system landscape where CareWare is focusing on.

Subsequently, an extensive overview of different 'commercial' systems is given and reviewed/discussed with respect to the 'to-be-developed' Careware system(s). From the benchmarking table shown at the end of this section, one can see that the available systems typically use modules which are not integrated into the textile. These are usually straps that can cause comfort issues and are not washable. While in the CareWare, the project partners aim to work to a fully integrated sensor in the textile, that is washable, flexible and moderately stretchable in a non-stigmatising way. Specifically for the patient-monitoring use case (UC1); although there are many hearth rate monitors, breath rate and accelerometers on the market, little of them are provided in a way of modular units that can be integrated by a confectioner into a textile. Therefore, the current examples are difficult to easily implement to hospitals. For this use case, we aim to develop modular units that can be integrated into different hospital garments (and sizes) for the patient.

The increasing variety of sensors, technical possibilities and their utilizations in human health status monitoring and evaluation, together with a significant increase in data mining methods, algorithms and corresponding software demands a significant development in algorithms and data processing for body monitoring. Therefore, in a following section of this deliverable, a more in-depth overview of current available technology blocks is given. The latter comprises the state-of-the-art in both connectivity and sensor components for on-body applications, electronic textiles developments and off-body communication/connectivity means (i.e. gateways), followed by a state-of-the-art overview of algorithms and data processing specific for body parameter monitoring.
It is clear that innovations in both domains are still necessary to bring the system technology solutions closer to the end-user expectations/needs.

Finally, this deliverable ends with an overview of the currently-available health platform solutions. Most existing platforms (with the exception of the Santech platform, which is part of the CareWare project) are based on the implementation of standardized data protocols for data exchange between the patient and the medical staff or between the members of the medical staff. In other words, they are more focused on disease management than quality of life.

The most innovative part of Careware relies on the definition of a global architecture of the eco-system rather than the selection of a particular platform technology. In this respect, the Careware project is aimed at providing insight on the optimal split of functionalities between all the components of the eco-system and providing the requirements for the health management platform in order to support the end-user quality of life, including his health and well-being.

1. SCOPE OF THIS DELIVERABLE

This deliverable intends to provide a (to-our-knowledge) complete overview of the state-of-the-art (baseline) for the CareWare technologies and its system(s). Therefore, the deliverable starts in section 4 with a recapitulation of the defined use cases (which were presented in deliverable D1.1) – in order to set the technology/system landscape where CareWare is focusing on.
Subsequently (in section 5), an extensive overview of different 'commercial' systems is given and reviewed/discussed with respect to the 'to-be-developed' Careware system(s).
In a following section of this deliverable, a more in-depth overview of current available technology blocks is given. The latter comprises the state-of-the-art in both connectivity and sensor components for on-body applications, electronic textiles developments and off-body communication/connectivity means (i.e. gateways), followed by a state-of-the-art overview of algorithms and data processing specific for body parameter monitoring. In section 8, the deliverable will give an overview of the currently-available health platform solutions.
The deliverable will end with conclusions and it will be made clear that innovations in most domains are still necessary to bring the system technology solutions closer to the end-user expectations/needs.

2. ASSOCIATED DOCUMENTS

2.1 APPLICABLE DOCUMENTS

A1 Project Full Project Proposal. Careware

2.2 REFERENCE DOCUMENTS

R1 D1.1 USE CASES SCENARIOS AND BUSINESS OPPORTUNITIES

3. TERMINOLOGY

3.1 ABBREVIATIONS

API	Application Programming Interface,
BCG	Ballisto CardioGraphy,
FCC	Federal Communications Commission ()
IoT	Internet of Things
ISM	industrial, scientific and medical (radio bands)
NFMI	near-field magnetic induction (
OHRM	Optical Heart Rate Monitor,
PPG	Photo Plethysmography

3.2 DEFINITIONS

None

4. SUMMARY OF THE CAREWARE USE CASES

4.1 PATIENT MONITORING - USE CASE 1

The first use case in the Careware project is ”Unobtrusive and comfortable monitoring of convalescent or disabled people to provide them with personalized treatment and help them maintain a high quality of life”. The patient is monitored in the hospital or at home in an unobtrusive, comfortable and transparent way. In this way, his quality of life can improve and he can receive personal treatment

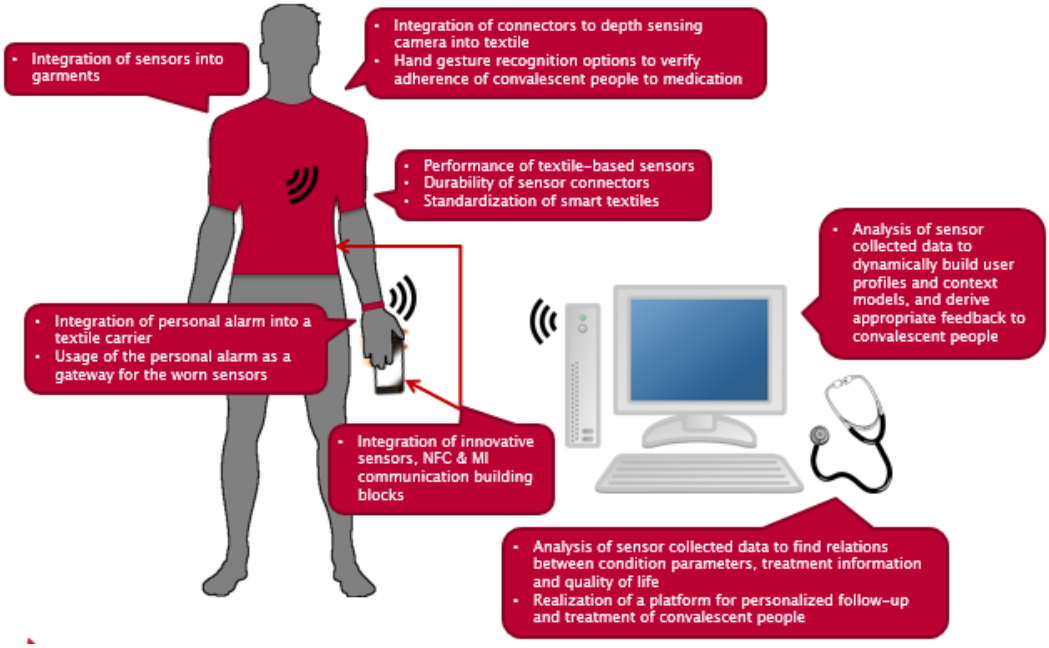


Figure 1. Patient monitoring

The monitoring system envisioned in this use case makes use of sensors and communication devices integrated into clothes, or any piece of equipment (such as patches, wristwatches, wheelchairs, and other garments) that can be easily carried by people in a non-stigmatizing and comfortable way.

It can be used by convalescent or disabled people, their nurses and doctors to enable a personalized follow-up and treatment. It provides nurses and doctors with accurate information of the status and evolution of their patients and inform these nurses and doctors of any potential problem. It monitors physiological and medical parameters but also adherence to medication and quality of life parameters.

4.2 HOME CARE FOR THE ELDERLY - USE CASE 2

In this use case, we are considering an elderly person living at home and feeling great and independent in his house with all his memories. This person has multiple risk factors of developing diseases and might already have one or several chronic diseases. Connected clothing will help elderlies stay at home longer despite having weaknesses, disabilities or chronical diseases that necessitate a continuous medical control.

The system is intended to spread early alert signal in case a problem occurs, going from the elderly himself (he would be able to tell the system in case of a false positive), to his neighbours or his family if he isn't able to respond to the alert, or directly to medical assistance in case of an emergency.

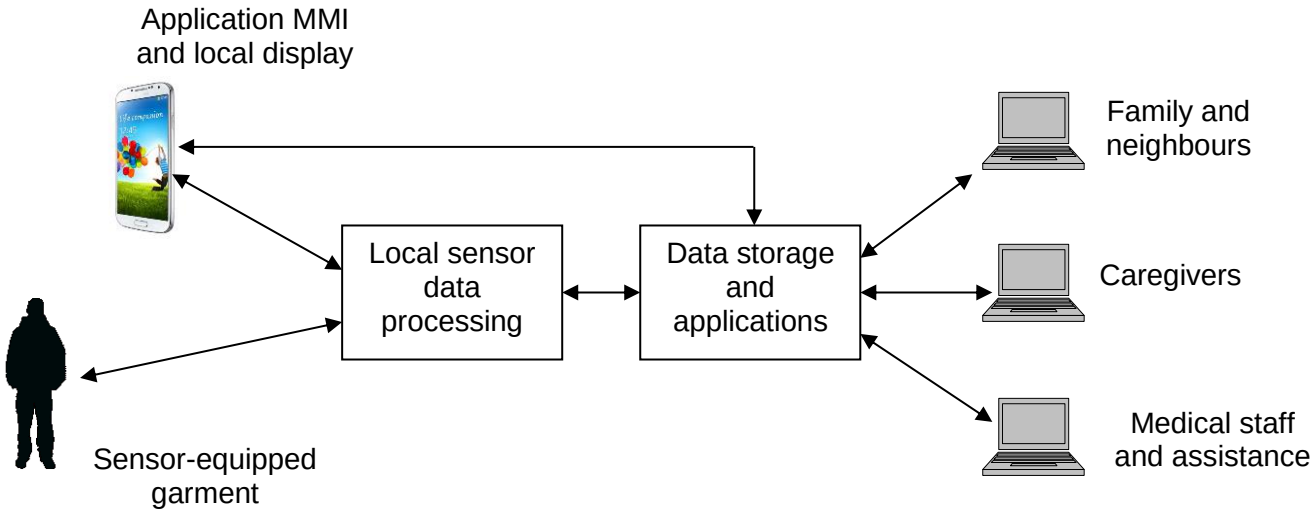


Figure 2. Home Care for the Elderly

The elderly should be equipped with appropriate garment in order to measure those physiological parameters that are pertinent to their weaknesses or risks. These garments may include the following:

- **socks** for monitoring pressure variation for movement and veinous return
- **shirt** for monitoring
  - circulatory functions (heart rate, blood pressure, electrocardiogram)
  - respiratory functions (frequency, amplitude, regularity, oxygen saturation)
  - hybrid functions (skin temperature - absolute and gradient, humidity), intestinal activity

  other garments for monitoring:
  - acceleration: motion, fall, activity, and tremor detection
  - information about the environment: CO, CO2, other toxic gas, light, UV exposition, outdoor activity

The equipment should integrate a personal device that will be used

- to display alerts and to allow acknowledgment of the alert by the elderly;

- to communicate with the other actors in order to receive recommendations, to send messages about his well-being or to interact with his social network.

4.3 SPORT AND WELLBEING - USE CASE 3

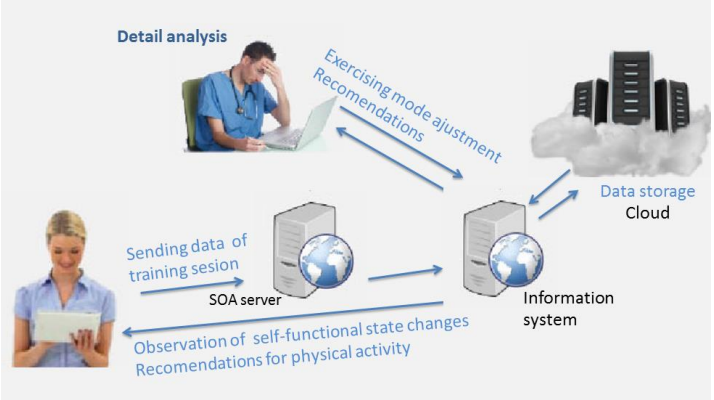
This use case, is considering unobtrusive, comfortable monitoring of functional state during training session allow individualized control of physical loads intensity and time, will help to increase effectiveness of training process and avoid negative inappropriate physical activity effects on health for sportsmen's, physically active persons and persons with heath disorders.

Now heart rate is usually used to control physical loads, but heart rate does not reveal many important physiological processes to be monitoring in order ensure safety and effectiveness of physical activity.

The CareWare system is able to efficiently perform sensor data processing and data fusion in order to visualize the holistic view of user's health status personalized, intuitively and trustworthy way and provide a feedback for user about individualized intensity and time of exercising control.

Again, social communities and different wearable sensors capturing physiological & mental data integrated with smart clothes can be used in motivating people to do more exercising. The CareWare is focusing on preventive actions in promoting comprehensive health and wellbeing among citizens for instance in sport training situation or in work communities that intent to courage people to exercise more.

A - Using real time platforms of CareWare system during training session



B - Using CareWare system after training sessions

Figure 3. Quantify yourself

Figure 3 A shows how real time platforms of the CareWare system wil be used during training session. The signals of Electrocardiography and accelerometer by blue tooth connection will be sent to mobile phone. Primary analysis of signals, decision making algorithm and real time feedback will be proceed on smart mobile phone. Moreover the distance observation of training session data and real time feedback of specialist will be possible via internet server.

Figure 3 B shows how the CareWare system will be used after training sessions.

Expected added value of the system beyond industrial state-of-the-art:

- Deliver ECG registering T-shirts with good quality ECG signal during physical activity
- Provide sensitive and informative methodology for real time excercise control
- Provide software support of movement and functional state monitoring system
- Using project experience create new related software products.

5. STATE OF THE ART IN WEARABLE SYSTEMS

5.1 OVERVIEW OF THE STATE OF THE ART

5.1.1 Introduction

Last year (2015) was definitely a big year for wearable technologies with IPOs (Fitbit), major acquisitions, (Misfit and Fossil, Recon Instruments and Intel) and major launches (Apple Watch, Samsung Gear VR, TAG Heuer Carrera Connected). According to IDC[1], the wearable market—which includes fitness trackers and smartwatches—will pass 111.1 million shipped devices in 2016, up from 80 million units shipped in 2015. And these numbers continue to climb. By 2019, IDC expects that number to nearly double, with vendors shipping some 214 million wearable devices.

Figure 4: Wearables ecosystem mapped by Wearable World News (2015).

The global wearable sensors market is increasing at a steady rate due to advancements in sensor technologies, wireless communication, power supply technologies and others. With increasing

[1] http://mobilesyrup.com/2015/12/18/worldwide-wearables-shipments-will-hit-200-million-by-2019-idc/

personal care and health consciousness, for tracking biometrics such as calories burnt, heart rate and others, the demand for wearable fitness trackers and other wearables are increasing. Rapid expansion of internet of things (IoT) is driving demand of wearable sensors devices in various application areas such as healthcare and fitness, consumer electronics and others.

Consequently, wearable (medical) technology is becoming a hot commodity. As these devices come to market, they have the potential to help both patients and clinicians (self) monitor vital signs and symptoms. In Figure 4, one can see that the wearable ecosystem is enormous. Research suggests that this ecosystem will be worth over $30B in 2018.

The infographic simplifies the major categories of wearable devices into glasses, clothing, watches, bands, headgear, and jewellery, with further segmentation into sub-categories of lifestyle, health & fitness, and entertainment.

From the figure below, it is clear that most of the wearable devices market is taken by watches and wrist bands. The share taken by clothing is currently negligible, but is expected to grow to about 5% in 2019, which equals to roughly 10 million units.

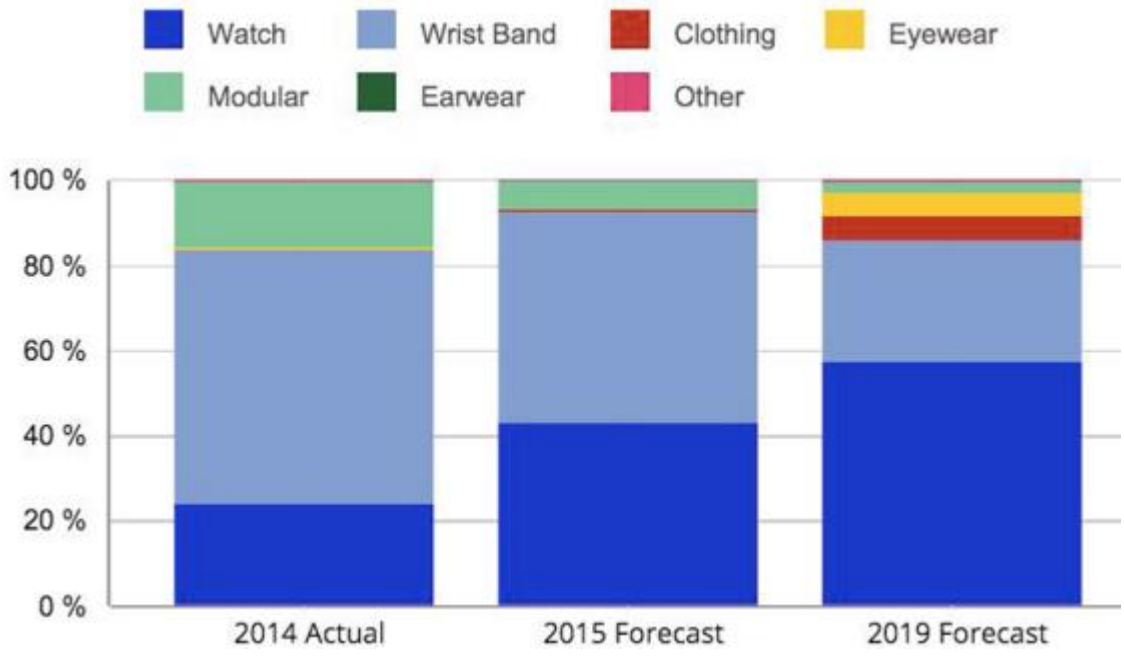


Figure 5: Worldwide wearable devices grouped by form factor – Market Share Forecast (Q3-2015)

Based on types, the global wearable sensors market can be broken down into motion sensors, image sensors, medical based sensors, position sensors, temperature sensors, inertial sensors, pressure sensors, and others. While the motion sensors had the largest share in the global wearable sensors market in 2014, the medical based sensors witnessed highest growth rate during the period 2012 to 2014. According to the new market research report on the "Medical Sensors Market by Sensor Type (Temperature, ECG, Image, Motion, & Pressure), Placement (Strip, Wearable, Implantable, & Ingestible), Application (Diagnostics, Monitoring, Therapeutics, & Imaging), & Geography - Global Forecast to 2022", the medical sensor market, in terms of value, is estimated to grow at a CAGR of 8.5% between 2016 and 2022. The market for medical sensor is expected to reach USD 15.01 Billion by 2022. The medical sensors market is projected to grow rapidly due to the increasing incidences of

cancer, acute myocardial infarction, and diabetes mellitus as well as the increasing number of postoperative rehabilitation patients across the globe[2].

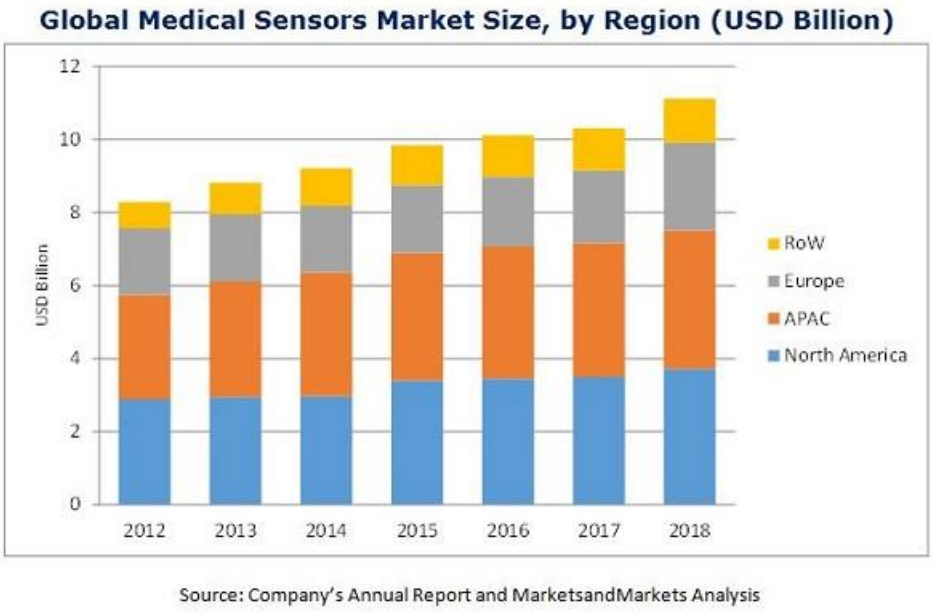


Figure 6: Marketsandmarkets forecasts

Almost all next generation wearables are incorporating biometric sensors into the devices to provide more advanced insights into activity and overall personal health. The most common biometric sensor in wearables is an optical heart rate monitor (OHRM). OHRM's use a process called photo plethysmography (PPG), which involves shining light into the skin and measuring perfusion of blood in the dermis and subcutaneous tissue by capturing the different amounts light refracted by varying volumes of blood flow that occur when the heart pumps

In the following paragraphs a brief description of different 'commercial' systems will be given and discussed with respect to the 'to-be-developed' Careware system.

[2] http://www.marketsandmarkets.com/PressReleases/world-sensors-healthcare-applications.asp

5.1.2 Wearable/mobile Localization and/or sensor systems

5.1.2.1 9Solutions IPCS

9Solutions is a leading manufacturer of Bluetooth Low Energy RFID and cloud technology based solutions for healthcare safety and work flow optimization. It provides our Integrated Positioning and Communicating System (IPCS) technology for system integrators, and sells safety and work flow optimization solutions built on the solid 9Solutions IPCS platform. Their solution portfolio comprises advanced solutions for hospitals, care homes and home care.

9Solutions Oy, Teknologiantie 2, 90590 Oulu, Finland

9Solutions IPCS is a wireless Bluetooth and SaaS-based real-time locating system (RTLS) and application platform that enables real-time tracking of people and equipment. The 9Solutions system works with cell phones, which can be used to protect "lone employees" -- medical and other personnel who might need assistance while doing their jobs.

Figure 7: 9Solutions system

9Solutions also targets healthcare patients, who can use the product as a *sophisticated nurse call* button. Residents of an assisted living facility, for instance, can be tracked -- and can call for help -- anywhere they go on the facility's premises while wearing a system tag such as a necklace or wristwatch. The system can notify caregivers if a resident has entered an unsecured area. The technology also can save personal activity profiles for each user and if any differ too much from the user's long-term activity, it can automatically send an alarm to caregivers.

5.1.2.2 Metria Wearable Sensor by Avery Dennison

Avery Dennison Corporation is a global manufacturer and distributor of pressure-sensitive adhesive materials (such as self-adhesive labels), apparel branding labels and tags, RFID inlays, and specialty medical products.

Avery Dennison, 207 Goode Avenue, Glendale, California, United States

The Metria™ platform is based on Avery Dennison® Medical Solutions advanced adhesives, materials and manufacturing processes in combination with a personal monitoring device for continuous physiologic monitoring developed by Proteus Biomedical, Inc. The user attaches the wearable sensor, which uses "skin-friendly" adhesive; the sensor collects data, such as the number of hours slept and breaths per minute; and the sensor wirelessly transmits a summary of the data to the user's or caregiver's device, such as a smartphone.

The patch will incorporate multiple sensors including ECG and an accelerometer that will allow measurement of heart rate, activity, sleep and other physiologic metrics. It will feature a skin-friendly adhesive that can accommodate day-to-day activity, such as exercising or taking a shower.

Possible applications for the remote technology include health and wellness, sports and fitness, and cardiac monitoring.

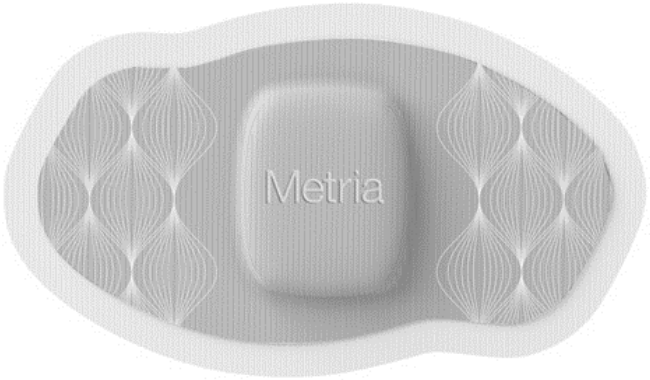


Figure 8: Skin adhesive with sensors from Metria

5.1.2.3 MioCare by Mitac

MITAC INTERNATIONAL CORP.

A leader in the global ICT industry, MiTAC International Corp. was founded in 1982. The company began operations in the Hsinchu Science Park (HCSP), Taiwan, and was the HCSP's first system manufacturer. With its global brands—Mio, Magellan, Navman, and TYAN —MiTAC distributes GPS and server products worldwide.

MiTAC Internat. Corp., No.200, Wen Hwa 2nd Rd., Kuei Shan Dist., Taoyuan City 33383, Taiwan (R.O.C.)

Mitac is manufacturer of OEM tablets http://www.mitac.com/TheBrands/Mio.html. They have developed a specific tablet for healthcare under the name MioCare. Besides the traditional tablet functions they have added:

- Increased drop resistance
- 2D scanner
- Hot swap battery

- Android drivers for specific functions.

MioCARE™ is focused on offering adaptable tablet products and bespoke mobile solutions for healthcare. We achieve this by putting the right technology into the hands of doctors and nurses. We work with users, IT teams and software providers to create solutions that reduce workloads and produce results.

Figure 9: MioCARE Tablet multi purposes

5.1.2.4 Bodymedia (as part of Jawbone)

In April 2013, Jawbone acquired BodyMedia. Almost immediately after the acquisition, it became clear that Jawbone was not interested in the BodyMedia brand or business, so much as the company's large patent portfolio (parts of which are at the heart of the company's ongoing legal dispute with rival Fitbit). On Jan 31, 2016 support for BodyMedia Fit mobile and web applications has officially come to an end.

Jawbone., San Francisco, California, US.

Figure 10: BodyMedia interfaces

The BodyMedia Feedback feature provides you with personalized feedback based on the data gathered from your Armband sensors, the foods you've logged, and your personal goals. The system analyses your daily Calorie Burn and food log data to predict whether you are falling short, right on track, or doing better than your daily calorie burn, activity, nutrition, and weight loss goals. If you are behind, it provides you with personalized feedback on how to reach your goals. The system will also provide tailored feedback content for praise and reminders as well as health and fitness tips.

5.1.2.5 Healthpatch MD (Vital connect)

Vital Connect (founded in 2011 in Silicon Valley) is a medical device and healthcare technology company applying advanced biosensor technology and surrounding data management systems to deliver an innovative biometric data measurement platform that supports decision-making paradigms of physicians and other healthcare professionals.

Vitalconnect, 900 East Hamilton Ave, Suite 500, Campbell, CA 95008 (US).

The HealthPatch MD is a new technology for healthcare professionals to be able to keep tabs on the vital information of their patients. The company behind this product is called Vital Connect. The HealthPatch MD is a biosensor that is reusable and it is embedded in a patch that can be disposed of. It has ECG electrodes and also has a 3 axis accelerometer that helps with keeping track of heart rate, breathing, temperature, steps, and even detects body position in case if a person has fallen.

The HealthPatch MD is BlueTooth capable and could be connected to any mobile device in order to look at real time data received through the biosensor. The HealthPatch MD has received FDA clearance in the United States and has been given regulatory approval throughout Europe. This product is also registered in Canada as well. www.vitalconnect.com is the place to go to get more information about the HealthPatch MD.

Figure 11: HealthPatch MD from Vitalconnect

5.1.2.6 Optiscan by Daza

Daza Opticare B.V. is a company, which develops and produces electronical devices for healthcare. The company was founded in 2000 to provide a solution to the growing number of fall incidents amongst elderly people. Encouraged by good results and the acknowledgement of professionals in health care, Daza has become market leader in the Netherlands in the field of electronic fall prevention and patient safety.

Daza Opticare BV, Bosstraat 30-32, 4704 RL Roosendaal, Netherlands.

The physical protection of the patient is an important aspect of patient care. This means they are protected from their own actions but also actions of fellow residents. Because restraint is no longer seen as a good solution, more and more health care institutions are now switching to preventive monitoring of patients to quickly observe potentially dangerous situations (for example a patient who is in danger of falling and decides to walk without any help). This monitoring can take place at the moment the patient prepares to get out of bed or rise from a chair. It can also be used if freedom of movement is restricted to just one room. In this case a door contact can monitor whether the door of the room is opened. In situations with falling patients, the man-down transmitter immediately sends an alarm signal. By activating a calling system, care assistants can be on the scene very quickly. In short, there is complete alarm coverage, depending on the needs of the patient.

Optiscan

This unique combination of infrared technology, dedicated software and wireless technology has proved to be a reliable and flexible alarm system in the prevention of falls. The Optiscan sensor is placed on the floor and views the space under the bed. The Optiscan is adaptable on all systems in

every setting. It detects when a client is trying to get out of bed at a very early stage. In case of an alarm, a signal is sent to the nurse. This early alarm signal gives the nurse the opportunity to respond swiftly, so serious harm can be prevented. Solid research has shown that with the use of the Optiscan, the number of fall incidents can be reduced considerably. In practice, it appears 85% of the clients are still on the edge of the bed when the care staff arrives in the room. Optiscan's benefits to the client and the experiences of care staff have contributed greatly to its success.

5.1.2.7 eNest by Nestwork

NESTWORK is a company that focuses on mobile safety innovation, by designing and manufacturing personal emergency response and tracking devices. NESTWORK solutions are clearly aimed at providing its users with the latest technology innovations and high quality products. Their users benefit from added freedom and a more independent lifestyle, increasing their quality of life and providing peace of mind to themselves but also their relatives and caregivers.

Nestwork, Place de la República Argentina 3, 28002 Madrid, Spain.

eNest is a mobile personal emergency response device that also tracks the user at all times, and should the user be experiencing an emergency situation, he or she can call for assistance quickly and efficiently. Additionally, the eNest features proactive alarms that will issue an alarm in certain emergency situations when the user is unable to do so, such as after a fall or accident.

Figure 12: eNest personal emergency device

Users and their relatives or caretakers will have access to a password-protected platform that can also be used to configure and personalize your eNest device based on your daily habits and preferences. Also, you can monitor your daily activities, or set a specific tracking area. All alarms and incidents will be registered on the platform to ensure better monitoring and checking. Your relatives or those close to you can access the platform at any time to find out where you are and display any alarm that has been issued.

5.1.2.8 Vivago

Vivago is a pioneer in personal health care technology and provides smart safety and well-being solutions. Vivago was established in 1994 to develop, sell, and market automatic safety solutions that can also monitor well-being and functional ability. Vivago provides safety solutions for the whole care chain. All our products are designed and made in Finland.

Vivago Oy, Självstyrelsegränden 6, 02600 Esbo, Finland.

Vivago's solutions are based on patented technology, which allows us to offer unique solutions for custom needs. Our solutions can cover nurse call systems, automatic alarm systems, wandering detection and continuous well-being monitoring.

Compared to regular nurse call systems, the VIVA solution has the same alarm buttons and integration interface. What is unique is that Vivago's automatic alarms provide extra safety for sudden emergencies. In an emergency situation it is possible to establish two-way voice communication to the room of the resident thanks to the Room POINT base station.

Figure 13: Vivago watch

The Vista VIVA software is an essential tool to support the health care work. The software makes modifying personal settings easy. This ensures the alarm settings on the CARE watch can always be customized to fit the wearer and further tweaked whenever necessary. The VIVA safety solution takes into account both the diverging needs of individual residents and the various approaches to health care of different service providers.
Additional features include integration with fire alarms and various telecommunication systems. If needed the VIVA solution can easily be complemented with Vivago GO wandering detection or Vivago VITA well-being monitoring.

5.1.2.9 Biosensetek

BioSenseTek (BST) is a leading-edged research and design company which focuses on development of bioelectrical-physiological sensor and signal processing instruments. The engineering group comprises of researchers from Miami, USA and Taipei, Taiwan who have been working in collaboration for the past years.

BioSenseTek Corp., 108 Greenwich Ct., Madison, New Jersey 07940, US.

VT2000, a centralized vital signs monitor, is specifically design to real-timely monitor the patient's vital signs. This product not only has an outstanding design in size (32 g), but a global leading technology in battery life (>7 days). The built-in functions include ECG, heart rate/pulse rate, respiration rate, skin temperature and indoor location tracking. In addition, the system also integrates external instruments like blood pressure, SpO2, glucose and infrared ear thermometer. The system simplifies the caring process and provides better caring quality for the patients and care providers.

Figure 14: Biosensetek tags for ECG

Biosensetek is a small company specialized in the development of tags for patient monitoring and localisation. They have an in depth knowledge of ECG.
The tag can be clipped on pads or on smart clothing (they work together with AiQ). Building blocks are the tag with alarm button and sensor electronics & pads + very small access point for localisation. The tags can perform:

- ECG
- Nurse call alarming
- Patient localization based on RFID
- Blood pressure devices can link with the tag through near field communication

5.1.2.10 VITALITI Medical Monitor (Cloud DX)

Cloud DX Inc. is a funded start-up in early revenue stage. We design, manufacture and export innovative breakthrough FDA cleared health

information technology products. On the cutting edge of our space, Cloud DX Inc is a top 7 finalist in the $10 Million Qualcomm Tricorder XPRIZE competition out of a total field of over 300 companies. Cloud DX was also awarded the 2015 Startup Canada Award for Innovation – Ontario.

Cloud DX, 100 - 72 Victoria Street South, Kitchener, ON N2G 4Y9, Canada.

The VITALITI system (from the company Cloud DX) promises to continuously record ECG, and measure the heart rate, heart rate variability, oxygen saturation, blood pressure, core body temperature, as well as parameters like respiration, movement, steps taken and calories spent.

Figure 15: VITALITI system (recording of ECG, heart rate…)

The main sensor is worn over the shoulders, with pads touching the chest doing much of the important sensing. There is also an ear lobe sensor that is in charge of monitoring the heart rate and oxygen saturation. The whole system can stay on for up to three full days, streaming the various health parameters continuously that can be retrieved at any time using a smartphone or tablet. It is Bluetooth capable and iOS and Android compatible.

That information is stored and then the app will give you information that will help alleviate and help for better symptoms. The app will help you with information on mobility exercises, how good your posture should be, and ways to eliminate stress.

5.1.2.11 QardioCore by QARDIO

QARDIO

Qardio was founded in 2012 by Marco Peluso (after his father suffered a stroke) to transform the healthcare industry with simpler, smarter and more effective solutions

for everyone: patients, doctors and healthcare providers. Unlike other industries, healthcare has not seen many impactful innovations over the past few decades.

Qardio, Inc., 115 Sansome Street, Suite 888, San Francisco, CA 94104, USA.

The QardioCore wearable ECG monitor is an easy to use monitor that straps around the chest. The sensors in it are able to monitor heart health and health status. It is a wireless monitor that does not need any kind of sticky patches or gels. The QardioCore has all of the activity tracking monitor capabilities as well and that information can be seen on a companion app, which is iOS and Android compatible along with BlueTooth capability.

The QardioCore is also associated with a cloud based system which allows for a doctor to monitor a patient in real time. This is another new product that is coming out by this company but details about it are not well known. It is being said that the product should be available to consumers and retails at $449.

Figure 16: QardioCore wearable ECG monitor

5.1.2.12 Adidas XCell and Micoach

Adidas AG is a German multinational corporation (since 1949) that designs and manufactures sports shoes, clothing and accessories headquartered in Herzogenaurach, Bavaria.
With the Micoach range of products, Adidas already offer a wide range of wearables for fitness and sports.

Adidas AG, Adi-Dassler-Strasse 1, 91074 Herzogenaurach, Germany.

Figure 17: MiCoach XCell + textile belt

Figure 18: MiCoach cardio frequency monitor

Measures cardiac frequency, speed, reaction speed, jump heights… compatible with the Xcell connected textile range of products. Data are not transmitted in real time but can be stocked for 7 hours before being downloaded to a smartphone. Sold 70€ in 2016.

Capture cardiac frequency measured and transmitted through Bluetooth. It is sold 61€ in 2016

5.1.3 Smart clothing or intelligent apparels

The term ***'intelligent apparel'*** describes a class of apparel that has active functions in addition to the traditional properties of clothing. These novel functions or properties are obtained by utilising special textiles or electronic devices, or a combination of the two. Thus, a sweater that changes colour under the effect of heat could be regarded as intelligent clothing, as well as a bracelet that records the heart rate of an athlete while he or she is exercising. Intelligent clothing can therefore be classified into three categories [1]:

- clothing assistants that store information in a memory and carry out complex calculations;
- clothing monitors that record the behaviour or the health of the person;
- regulative clothing, which adjusts certain parameters, such as temperature or ventilation.

Figure 1 shows the stages of development that lead to the elaboration of communication apparel, including the inclusion of telecommunications functions. This figure also classifies apparel in terms of intelligence and communication. All of the technologies used in the process of elaboration (high-performance textiles, electronics, communications and telecommunications) are related to blocs describing the properties that can be useful in the conception of communication apparel. All of these technologies add new functions to the communication apparel, leading to changes in the way we define this apparel. The properties of intelligent and communication apparel, and their potential targets and applications, are detailed in the next sections.

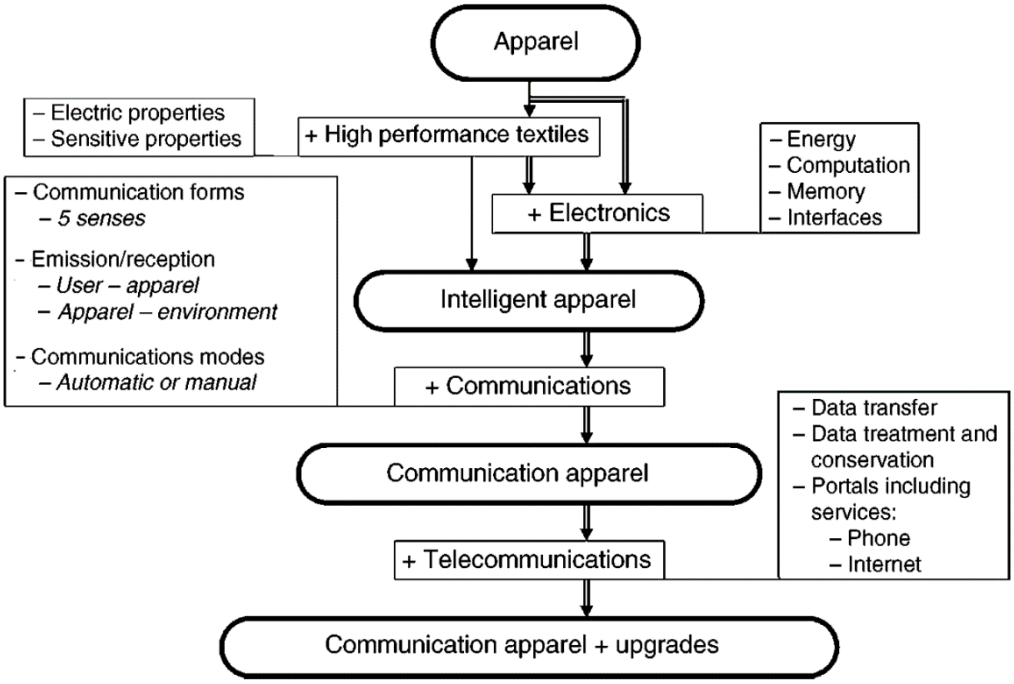


Figure 19 Intelligent apparel evolution (taken from Tao, X. Wearable Electronics and Photonics. The Textile Institute: Woodhead Publishing Limited, 2000)

Scientists seek to develop smart clothing that possesses many of the useful properties of computers – the ability to store and manipulate data; display images, text, and video; connect to the Internet; offer input devices; and so on. Other possible features of smart clothing include the ability to detect chemicals in the air, quickly harden on contact with a speeding bullet, change colour or opacity, generate power from the wearer's movement, record the wearer's speech and activity, and even project an image of the scene behind the wearer, creating a crude form of camouflage-based invisibility. Various "power suits" in science fiction and fantasy display these qualities.

Smart textiles and wearable devices can monitor your vital signs as you go about daily life. These clever clothes already exist and look set to find a market niche especially in elite sport and healthcare. Italian firm *Smartex* developing clothes can keep healthy and active at the same time. Tiny sensors woven into the fabric collect information about the wearer's vital signs (respiration, heart rate, surface and core temperature) and movement, which can be monitored remotely using embedded GPRS transmitters. In the sections below, some more examples of innovative clothing are presented.

5.1.3.1 AiQ Smart Clothing

AiQ Smart Clothing Inc. is one of the subsidiaries of TexRay Industrial co., a publicly global fabric and apparel company based in Taiwan. AiQ Smart Clothing Inc. plays a vital role within the e-Textile supply chain by offering a complete and vertical integration of wearable technologies to its customers.

AiQ Smart Clothing Inc., 8F, No. 426, Linsen N.Rd., Taipei City 10451, Taiwan

AiQ develops "smart textiles" for a range of custom apparel, including a vital sign monitoring system in a T-shirt. The BioMan t-shirt has ribbed "smart sleeves" that measure the user's heart rate, respiration rate and skin temperature. The garment can be further customized to measure skin moisture and electrophysiological signals such as ECG, electroencephalography (EEG), or electromyography (EMG). AiQ sells other specialized "smart" jackets and vests. For instance, the SolarMan vest has built-in solar panels capable of recharging the user's electronic devices. The CameraMan jacket has a built-in HD camera in the left breast pocket area, and the ArmorMan pullover has padding that stiffens on contact to protect the wearer.

5.1.3.2 Quanta “Home & Health”

Quanta Computer is the largest notebook computer ODM company in the world. In 2009 they started an internal spin-off company focusing on healthcare. They have developed a complete cloud based solution for “home care” and “service flats” called “HomeHub centered Services”.

QOCA™ home is a cloud-based solution designed to enable remote home care services primarily for the elder populations, which would in turn empower the individuals to be better connected with care providers and families to enjoy aging in place and to reduce the risks and costs of long- term conditions. As the backbone of the solution, the QOCA™ home Cloud encapsulates Quanta Computer’s unique QMULUS® private cloud infrastructure and application service modules to support scalable operation of remote home care services. A comprehensive management and service monitoring tool for the service operators is accessible through a web browser
The picture below shows what is included in the solution:

- A HomeHub 15 inch terminal with:
  - HD video camera
  - Sensor interface (Bluetooth 3.0)
  - Sound system (5W)
  - WLAN interface
  - Data storage
- HD video conferencing device for doctors (4 images: doctor, patient, nurse, insurance company)
- Health Watch (18h lifetime): sensor interface, ECG
- Monitoring software: logging and analysis of all sensor data
- Cloud based storage
- Smart clothing: integrated pads for sensing.
- Tag that can be clipped on the clothing for ECG, HR, EE, Activity, RR, Fall detection monitoring
- Tablet with HD front camera
- Mobile phone app with similar functions as HomeHub

Figure 20 Quanta “Home & Health” solution

5.1.3.3 Boogio

Boogio is a set of thin sensors and tiny computers installed in shoes that connect data and technology to people. It can be leveraged with fitness, sports training, digital health, rehabilitation, mobile experiences and virtual reality. It can even be customized to meet the needs of developers to design new possibilities. boogio.com

Figure 21 Boogio sensors in shoes

Boogio is wearable technology for your feet with precision data that moves way beyond simple step counters. Non-intrusive sensors indicating foot pressure, balance and 3D movement hide in the shoe. Boogio leverages the power of IoT and connects it with people.

ARTIK likewise represents the democratization of hardware for IoT startups and is accelerating Boogio's development cycle and application potential. It provides a solid foundation with state-of-the-art chips optimized for stable, secure, low-powered integration with wearable technologies such as Boogio.

Boogio accurately captures body movement from the ground up to provide contextualized data for individuals during any activity. It can pair with other wearable sensors to build a foundation for Body Area Networks, creating a personal Internet of You. ARTIK's open and modular design enables quick iterations with hardware similar to software development, and is scalable for the many applications of Boogio. Now people can train smarter, play harder, work better, be safer, and interact seamlessly with today's digital connected world.

Recently Boogio was tested at Celebration Health as part of a partnership with Florida Hospital to understand ways to help kids recover in pediatric rehabilitation. This ongoing collaboration is a pioneering effort to explore how hospitals can utilize technology in digital health and capitalize on meaningful engagement with the patient within and outside the hospital walls.

5.1.3.4 Ambiotex t-shirt

ambiotex, pioneer in the field of wearable technologies, develops and produces a smart sensor shirt for the health conscious individuals, who have the desire to measure, analyze and share their vital data in order to improve their performance. http://www.ambiotex.com/

Lauterenstr. 37, 55116 Mainz, Germany

The TechUnit is an extremely important component of the ambiotex t-shirt. The slender plastic case can be fixed to the shirt – or removed – in one simple movement and is compatible with any ambiotex t-shirt. Direct contact between the TechUnit and the t-shirt permits the collection and exchange of biometric data.

Figure 22 Ambiotex t-shirt with integrated sensors

5.1.3.5 BioHarness™ by Zephyr (Medtronic)

Zephyr™ Performance Systems	Zephyr™ Performance Systems, now a part of Medtronic, is a global leader in real-time physiological and biomechanical monitoring solutions for the Defense, First Responder, and Pro and Collegiate sports markets.

1 Annapolis Street, Suite 200, Annapolis, MD 21401, USA

The BioHarness™ 3 (http://www.zephyranywhere.com/products/bioharness-3) is the premiere compact physiological monitoring module that enables the capture and transmission of comprehensive physiological data on the wearer via mobile and fixed data networks – enabling genuine remote monitoring of human performance and condition in the real world. Uses Bluetooth to provide heart rate, RR Interval, breathing rate, activity level, speed & distance.

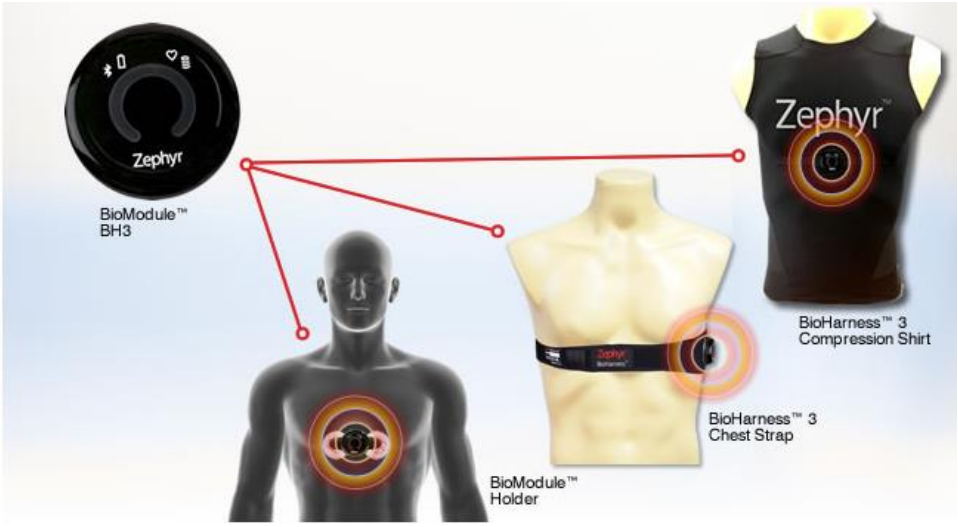


Figure 23 BioHarness solution

5.1.3.6 Hexoskin

HEXOSKIN
WEARABLE BODY METRICS

Hexoskin (Carré Technologies inc.) is an independent company founded in 2006.
Hexoskin's mission is to record and organize personal health information and make it accessible and useful. To get better and more affordable health and fitness services, people will need to wear health sensors. The best place to put sensors on your body is inside good-looking clothing that makes you feel and look smarter about your health. That's what we did with the Hexoskin smart shirt. Connectivity, increased interest for health and fitness, population aging and the consumerization of healthcare are strong tailwinds for Hexoskin.

5800 Rue Saint-Denis #402a, Montréal, QC H2S 3L5, Canada

Hexoskin's biometric shirt is a portable lab that monitors cardiac, respiratory, and activity data
Hexoskin Product Specifications. Monitors, Features, Biometric Shirt and Data & Tech
What Hexoskin Monitors

- Heart Rate, HRV (allowing estimating stress and fatigue), Heart Rate Recovery, and ECG.
- Breathing Rate (RPM), Minute Ventilation (L/min).
- Activity intensity, peak acceleration, steps, cadence and sleep positions.

Features

- 14+ hours of battery life (multiple trainings), 150+ hours of standalone recording.
- Bluetooth connectivity with iPhone, iPad and Android.
- Data validated by independent research labs.

- Designed and assembled in Canada.
- Safe for any kind of activity.

Biometric Shirt

- Machine washable, high-performance Italian fabric.
- Quick dry, breathable, lightweight, anti-odour, chlorine resistant, UV protection.

Data and Tech

- Open Data API allows you to download raw data and use your own analytics software.
- Analog 256Hz ECG data.
- Analog dual-channel 128Hz breathing sensors.
- Analog 3D 64Hz acceleration.

Figure 24 Hexoskin's biometric shirt

http://www.hexoskin.com/

5.1.3.7 OM Signal

The Little Black Box: The data module records and streams continuous, real-time biometric data from your shirt to your phone
• Power through 30 workouts

• Seamless Integration
• Bluetooth connectivity
• Water Resistance

Data including:
• Heart Rate
• Calories burned
• Time spent in desired Training Zones and Movement Intensity

Workout Email Report: See peak and average heart rate, calories burned per hour and session, average kinetic intensity, time spent in each targeted training zone and every breathing and heart rate alert received on the application.

Application reads:
• Push Gauge - measures increases and decreases in intensity
• Training Zones
• Heart Rate Alerts
• Breathing Alerts
• Leaderboard - how does your performance measure up against your personal best and your friends?

5.1.3.8 Athos

The Core:

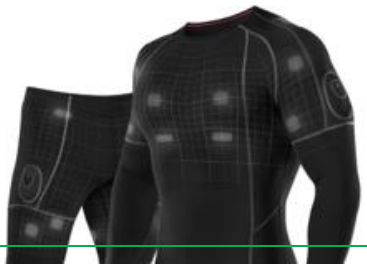
Collects and interprets information from the gear and sends it to your mobile device.
• 10 hours of continuous battery life
• Weighs 20g, 2.5in tall
• Impact resistant
• 6-axis accelerometer

It includes: EMG (electromyography) - identifies Muscle Effort, Muscle Fatigue, and Muscle Target Zones (Building, Toning, Under Training vs Over Training)

Brain of the system, it only needs one Core to work with any Athos garment.

It detects:
• Heart rate, heart rate variability and recovery rates
• Proper breathing patterns

The gear:



• Sensors are built into the fabric
• Warp Knit - Provides stability
• Flat Seam Construction - Avoids chafing
• 4-Way Stretch
• Sweat Wicking - Keeps wearers cool and dry
• UPS 50 Treatment
• Machine Washable

The app:

Actionable insights allow you to exercise correctly, avoid injury, and get real-time results.
Possible actions:
• Select goal and identify target score
• See insights or review after each set
• Workouts are automatically logged to track progress
• View how hard each muscle is working, whether you have correct form, or using the right muscles

5.1.3.9 Sensoria

Socks:

• Infused with proprietary 100% textile sensors
• Paired with a Bluetooth Smart detachable anklet
• May help identify injury-prone running styles (heel striking, over pronating, etc…) and leverage mobile app to coach runner in real-time via audio cues

Measures:
• Step Counting
• Speed
• Calories
• Altitude
• Distance

Tracks:
• Cadence
• Foot landing technique
• Weight distribution on the foot as your walk and run

Fitness shirt / bra:

Comfortable, consistent, and accurate heart rate data connected to your favourite HRM and mobile application, allowing you to optimize your fitness activity and improve performance.

• Made in Italy
• Machine Washable
• Compatible with Sensoria-HRM, Polar H7, and Garmin Premium

5.1.3.10 SenseCore

Core:

Weighing in at 17g each.
Parameters: Medical grade ECG, heart rate, calories, EPOC (excess post-exercise oxygen consumption), true respiration, breath rate, body temperature, 3-axis acceleration, speed/pace, distance, cadence, total steps.

Garment:

Made from compressed and lightweight fabric
• Fast-drying
• Anti-UV protection
• Chlorine resistant
• 4-way stretching
• Flat seams
• Light reflective
• Ventilation

5.1.4 Other references cited in the PROPOSAL

5.1.4.1 Activity

Examples include Actigraph Activity monitor, Dynaport Move Monitor, Pegasus Motion-X, Fitbit (http://www.fitbit.com/flex), Jawbone (http://www.jawbone.com), iHealth (http://www.ihealthlabs.com/) and Withings (http://www.withings.com/). Nokia, Apple, and Android phones have been used to detect walking, jogging and sitting.

5.1.4.2 Positioning and live tracking services

Based on a comprehensive state of the art study completed in 2011/2012, in which Cityzen Sciences has concluded with a set of industrial partners specialized in textile and electronic manufacturing (http://www.bluelinea.com/Bluelinea/Home.html) and the Vivago Care watch (http://www.vivago.fi/tuotteet-ja-palvelut/kellot/care-8001/)

5.1.4.3 Heart rate measurement

Since then many other products have arrived on the market (Suunto…), improving the wear ability through textile bands (e.g. by Clothing+: http://www.clothingplus.fi), or adhesive patches (http://vancive.averydennison.com/en/home/solutions/metria.html) and the accuracy, eventually allowing for the use of heart-rate variance for deriving breathing rhythms, sleep quality, stress (e.g. Firstbeat: http://www.firstbeat.fi, and Aerotel medical systems: http://www.aerotel.com/en/) and for long-term observations (multiple days). Recent developments have focused on sensing heart rate from the wrist using e.g. photoplethysmography (PPG). Examples include MIO Alpha, ePulse2, and Omron HR210.

5.1.4.4 Sleep quality and circadian rhythm

Beddit (http://www.beddit.com) provides a sensor device based on ballisto cardiography (BCG), a scientific method for measuring cardiorespiratory functions. It detects the tiny movements caused by respiration and heartbeats, and turns them into useful sleep and wellness information and guidance.

5.2 BENCHMARKING VERSUS CAREWARE

§	*Solution/ Company*	*Application*	*Functionalities*	*Link to UCs*	*Integrated in textile*	*Performance improvements in CareWare*
5.1.2.1	9Solutions	Healthcare	Localization, alarming	1	No	Sensor Textile
5.1.2.2	Metria – Avery Dennison	Health and wellness, sports and fitness	ECG, accelerometer	2, 3	No	Platform Textile
5.1.2.3	Mitac	Healthcare	Care efficiency	1	No	Sensor Textile Platform

§	Solution/ Company	Application	Functionalities	Link to UCs	Integrated in textile	Performance improvements in CareWare
5.1.2.4	Bodymedia	Sports, fitness, health	Calorie burn	1, 2, 3	No	Textile Open platform
5.1.2.5	VitalConnect	Healthcare, sport and fitness	ECG, accelerometer	1, 2, 3	No	Textile, open platform
5.1.2.6	Daza	Healthcare	Fall detection	1, 2	No	Sensor Textile Platform Communication
5.1.2.7	Nestwork	Health and home	Alarming and tracking	1, 2	No	Sensor Textile
5.1.2.8	Vivago	Homecare	Alarming and tracking, voice, wellbeing	1, 2		Sensor Textile Platform
5.1.2.9	Biosensetek	Health, vital signs monitoring	ECG, heart rate/pulse rate, respiration rate, skin temperature and indoor location tracking	1	No	Open platform
5.1.2.10	Cloud DX	Health, vital signs monitoring	ECG, PPG, core temperature, accelerometer	1, 3	No	Full system integration, textile
5.1.3.1	AiQ smart clothing	Health	heart rate, respiration rate and skin temperature	1, 2	Yes	Full system integration
5.1.3.2	Quanta Home & Health	Health and home	ECG, HR, EE, Activity, RR, Fall detection monitoring	2	Yes	Open platform
5.1.3.3	Boogie	Sports, fitness, health	Movement	1. 2. 3	Yes	Integration
5.1.3.4	Ambiotex	Sports	ECG, breath monitor	3	Yes	enduser[2]
5.1.3.5	BioHarness	Sports	heart rate, RR Interval, breathing rate, activity level, speed & distance	3	semi	Integration[1], enduser[2]
5.1.3.6	Hexoskin	Sports, fitness, airspace, health	ECG, accelerometer, G-force, breath rate	1, 3	semi	Integration[1]
5.1.3.7	OMSignal	Sports	ECG, accelerometer, breathing alerts, intensity, zones	3	Semi	

§	Solution/ Company	Application	Functionalities	Link to UCs	Integrated in textile	Performance improvements in CareWare
5.1.3.8	Athos	Sports	ECG, accelerometer, EMG, muscle target zones, breathing rate	3	Semi	
5.1.3.9	Sensoria	Sports	Heart rate, accelerometer	1, 3	Semi	
5.1.3.10	SenseCore	Sports, Health, wellness	ECG, breath rate, accelerometer, respiration, body temperature, speed/pace	1, 3	Semi	

Review the benchmarking table on the previous pages; one can make the following observations/remarks:

1. Integration aspect: The wearable textile uses modules which are not integrated into the textile. These are usually straps that can cause comfort issues and are not washable. In the CareWare project, we aim to work to a fully integrated sensor in the textile, that is washable, flexible and moderately stretchable in a non-stigmatising way.
2. End-user related: The wearable textile has not been developed for the same end user. The technology in the CareWare project will be implemented for a different user group (see use cases).
    a. Specifically for the patient-monitoring use case (UC1); although there are many hearth rate monitors, breath rate and accelerometers on the market, little of them are provided in a way of modular units that can be integrated by a confectioner into a textile. Therefore, the current examples (see table below) are difficult to easily implement to hospitals. For this use case, we aim to develop modular units that can be integrated into different hospital garments (and sizes) for the patient.
3. Sensor related: There is clearly a lack of devices that measure specific (body) parameters
4. Platform/system related: most systems are closed and no interoperability is possible.

6. STATE OF THE ART IN TECHNOLOGY BLOCKS

6.1 (ON-BODY) CONNECTIVITY

In IoT, one of the key features is wireless communication. Many wireless protocols and many wireless gateways will be supported Wide area wireless (GPRS, 3G, LTE) and short range wireless will be offered with integrated gateways (Bluetooth 4.0, Wi-Fi, 6loWPAN, ZigBee IP, ZigBee Pro, UHF, 802.15.4). Wireline access to the cloud will be provided for data storage and analytics. In Figure 25: Basic trade off of **bandwidth** versus distance for various protocols.

, the network data rate of different protocols is compared with its range. Wide areas are served with 2G/GPRS, 3G and LTE while Wi-Fi, Bluetooth 4.0, ZigBee Pro, ZigBee IP, 6loWPAN, UHF and 802.15.4 serve more local needs.

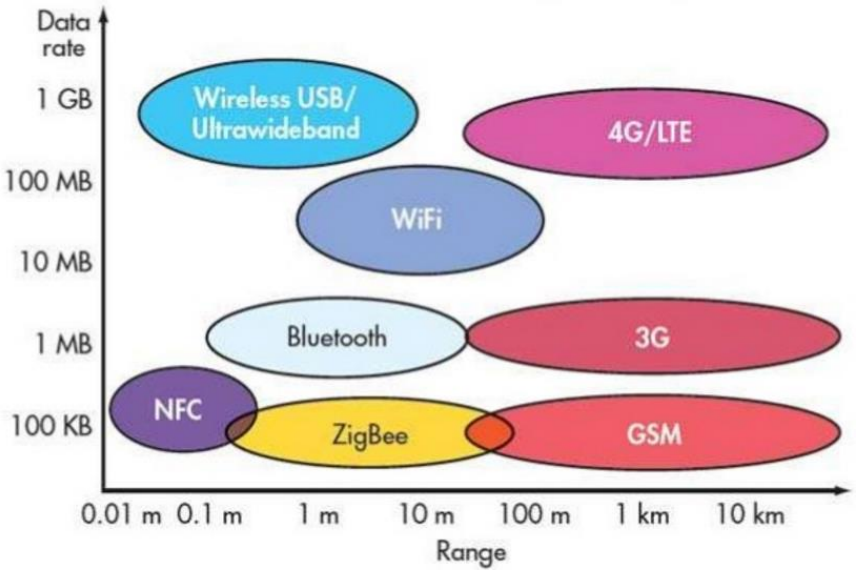


Figure 25: Basic trade off of bandwidth versus distance for various protocols.

Many wireless technologies (such as Bluetooth and Wi-Fi) operate at or near 2.4 GHz. In 2001, the Federal Communications Commission (FCC) opened the 2.4-GHz band to public use. This resulted in an influx of products that use this band. However, the high-frequency nature of the 2.4-GHz signal also results in a short wavelength that does not propagate well through and around the human head and body.

The 900-MHz ISM is a frequency band used for medical devices (e.g. hearing aids). A 900-MHz signal will propagate through and around the body with less signal degradation than is encountered with a 2.4-GHz signal, making it the only stand-alone option currently available for both far-field wireless transmission and reliable ear-to-ear communication.

A third frequency band used within medical devices for wireless data transmission is near-field magnetic induction (NFMI). Wireless communication through NFMI uses technology similar to a traditional tele coil. The range of frequencies used in hearing aids for NFMI data transmission typically falls between 3 and 15 MHz this frequency range allows for easy propagation through and around the human head and body.

In the table below, a comparison between the different communication standards has been made. Each of them has pros and cons. However, for on-body communication BLE and NFMI are most promising and therefore will be discussed in more details in the next sections.

	Low Energy Bluetooth	ZigBee	NFC	Low Power WiFi
Frequency (MHz)	2402 – 2482	868 - 868.8, 902 - 928, 2402 – 2482	13.56	2400 - 2500
Channels	3	16	1	3
Modulation	GFSK	BPSK & QPSK	ASK	64QAM
Max potential data rate	1 Mbps	250 Kbps	424 Kbps	54 Mbps
Range	10m	100+m	10cm	30m
Power Profile	Days	Months/Years	Months/Years	Hours
Complexity	Complex	Simple	Simple	Complex
Nodes/Master	7	65,000	1+1	
Extendibility	No	Yes	No	Yes [37]

Table 1: Technical comparison of different types of network protocols.

6.1.1 Bluetooth

The fast-growing wearables market has huge potential that also encompasses smart glasses, headsets, activity monitors, child and pet monitoring, medical aids, head- and hand-mounted terminals and cameras—all the way to smart clothing. And the majority of these products by far rely on the connectivity of Bluetooth technology. Even Apple is centring its wearables strategy on Bluetooth and Wi-Fi. However, it must also been said that Bluetooth is not iProducts friendly. BLE is natively compatible with iPhone, iPads etc. Bluetooth needs a MFi chip to be able to exchange with an iProduct. MFi literally means “Made For iProducts”

Bluetooth is a wireless technology for transferring data between two devices that are in close proximity with each other, and it has truly changed the world. The networks that it operates on are known as Personal Area Networks (PAN), and these connections are as secure as they come and offer no risk of intrusion or theft of data.

The newest Bluetooth version (v4.0) introduces Bluetooth Low Energy (BLE), a new protocol that allows for long-term operation of Bluetooth devices in low-volume data transmission. BLE enables smaller form factors, better power optimization and usage of coin cell batteries that can support wireless operation for 12 months plus.

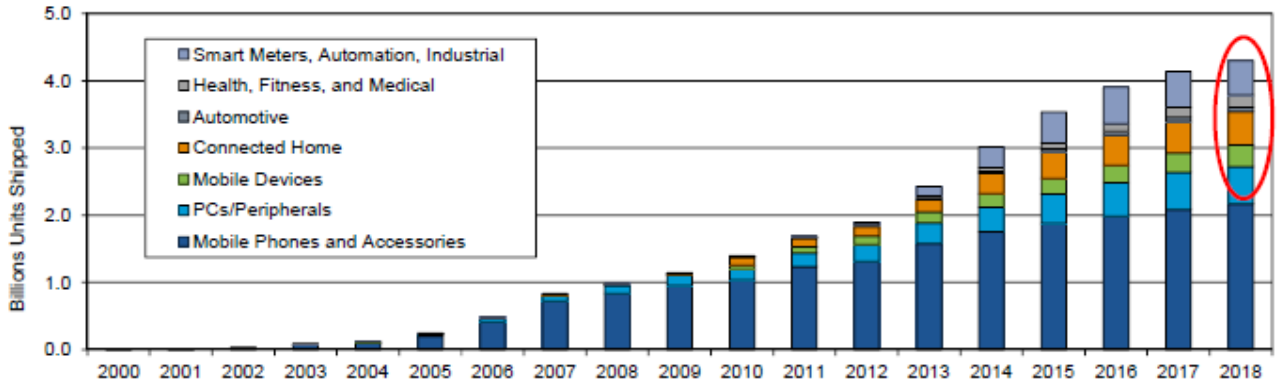


Figure 26: Bluetooth Enabled Device Annual Shipments, Major Markets – World Market Forecast 2000 to 2018. Source: ABI Research, Bluetooth Service Potential of BLE for Cable Replacement Solutions

BLE opens the door to new opportunities for developers and manufacturers of Bluetooth-enabled devices and applications, creating new areas of application for low-power wireless devices. The next few years one will see an increase in Bluetooth Smart products and applications, which will stimulate the expansion of BLE devices into markets, they currently do not serve. OEMs are especially excited to see BLE's presence in the industrial market. As BLE positions itself to be a key technology in the wireless industrial arena, more and more companies are looking to add BLE to a wide array of industrial devices. According to a report by ABI Research titled, "Emerging Bluetooth Verticals,"[3] cumulative shipments of BLE-enabled devices are forecast to exceed 20 billion devices by 2016 and 30 billion devices by 2018. Additionally, ABI estimates that in 2012 there was an installed base of 3.6 billion Bluetooth-enabled devices. By 2018 this is forecast to grow to almost 10 billion.
Bluetooth is so very popular in use of mobile and wearable device, because of its advantages:

- Bluetooth does not require a clear line of sight between the synced devices. This means that the devices need not be facing each other, and it is also possible to carry out transfers when both the devices are in separate rooms. The maximum range that it offers is 100 meters[4], but this range is not the same for all similar connections. It depends on the nature of the devices and the version that they operate upon.
- The processing power and battery power that it requires in order to operate is very low. This makes it an ideal tool for so many electronic devices, as the technology can be implemented pretty much anywhere.
- The chances of other wireless networks interfering with yours are very low. This is because of the low-powered wireless signals that the technology adopts, and also because of something known as frequency hopping.

Nevertheless, there are also some drawbacks of Bluetooth technology:

- Though the transfer speeds are at around 25 Mbps, certain other technologies like Wi-Fi Direct can offer speeds up to 250 Mbps. This is an area that can be improved upon in the near future.
- The battery usage during a single transfer is negligible. However when the device is left switched on in their devices, it will inevitably eat into the battery of these devices, and lowers the battery life considerably.
- The electromagnetic radiation used by Bluetooth to transmit data does not easily pass through the human body, these devices must use a lot of power and therefore it is not very suited for on-body communication.

[3] https://www.abiresearch.com/press/bluetooth-low-energy-devices-account-27-total-blue/

[4] There are different classes of Bluetooth, based on power dissipated and corresponding maximum range. The class I devices emit a power of 20dBm and have a range of maximum 100m, while class III has 0dBm and only 1m range.

6.1.2 Near-Field Magnetic Induction

NFMI is a mature technology with a proven track record in the hearing industry. A near field magnetic induction communication system is a short range wireless physical layer that communicates by coupling a tight, low-power, non-propagating magnetic field between devices. The concept is for a transmitter coil in one device to modulate a magnetic field which is measured by means of a receiver coil in another device.
The most known NFMI radio solutions are the NxH2280 family (from NXP) of fully integrated single-chip solutions enables wireless audio streaming and data communication using NFMI. These chip sets feature second-generation NFMI technology, an integrated ARM Cortex-M0 processor and a CoolFlux DSP for audio processing.
The benefits of NFMI technology lie in a few different areas. First, the hardware used in NFMI data transmission is well established, making it accessible for all hearing instrument manufacturers. The fundamental drawback to the use of NFMI is limited transmission range. Its use of magnetic signal transmission, similar to a tele coil, results in a wireless signal that degrades quickly. Specifically, the magnetic signal degrades approximately proportionally to the inverse of the transmission distance cubed, whereas with far-field or long-distance transmission methods (e.g. 900-Mhz and 2.4-GHz), signals degrade at a rate proportional to the inverse of the distance squared. For this reason, most modern hearing aids using NFMI have a transmission range that falls within 1 meter of the hearing aids.
The range of NFMI wireless transmission has been the impetus for the development of intermediate relay accessories that facilitate wireless communication over longer distances. The relay device remains close to the hearing aids, translating the short-range NFMI signal from the hearing aids to a longer-range transmission method, such as Bluetooth.

6.2 (ON-BODY) SENSORS

Wearable sensors are used to gather physiological and movement data thus enabling patient's status monitoring. Sensors are deployed according to the (clinical) application of interest. Sensors to monitor vital signs (e.g. heart rate and respiratory rate) would be deployed, for instance, when monitoring patients with cardiac issues. Sensors for movement data capturing would be deployed, for instance, in applications such as monitoring the effectiveness of home-based rehabilitation interventions in stroke survivors or the use of mobility assistive devices in older adults.
Currently, inertial measurement unit sensors (such as gyroscopes, accelerometers and barometers) and bio potential sensors are dominating the application space. However, according to a recent market report of IDTechEx, chemical sensors will take a considerable market share by 2020 (see figure below).

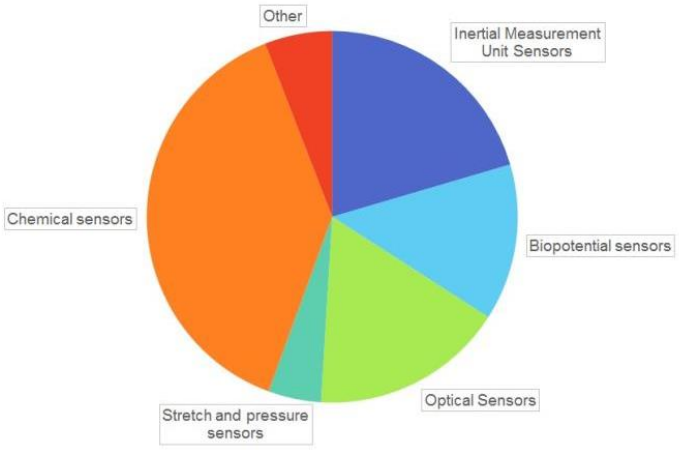


Figure 27: Relative market size by wearable sensor type in 2020 (according to IDTechEx[5], 2015)

6.2.1 Vital sign (bio potential) sensors

There are many sensors, which are used to explore vital signs. A summary of the different vital signs and locations on the body where they can be monitored is shown in Figure 28:

[5] http://www.idtechex.com/research/reports/wearable-sensors-2015-2025-market-forecasts-technologies-players-000431.asp

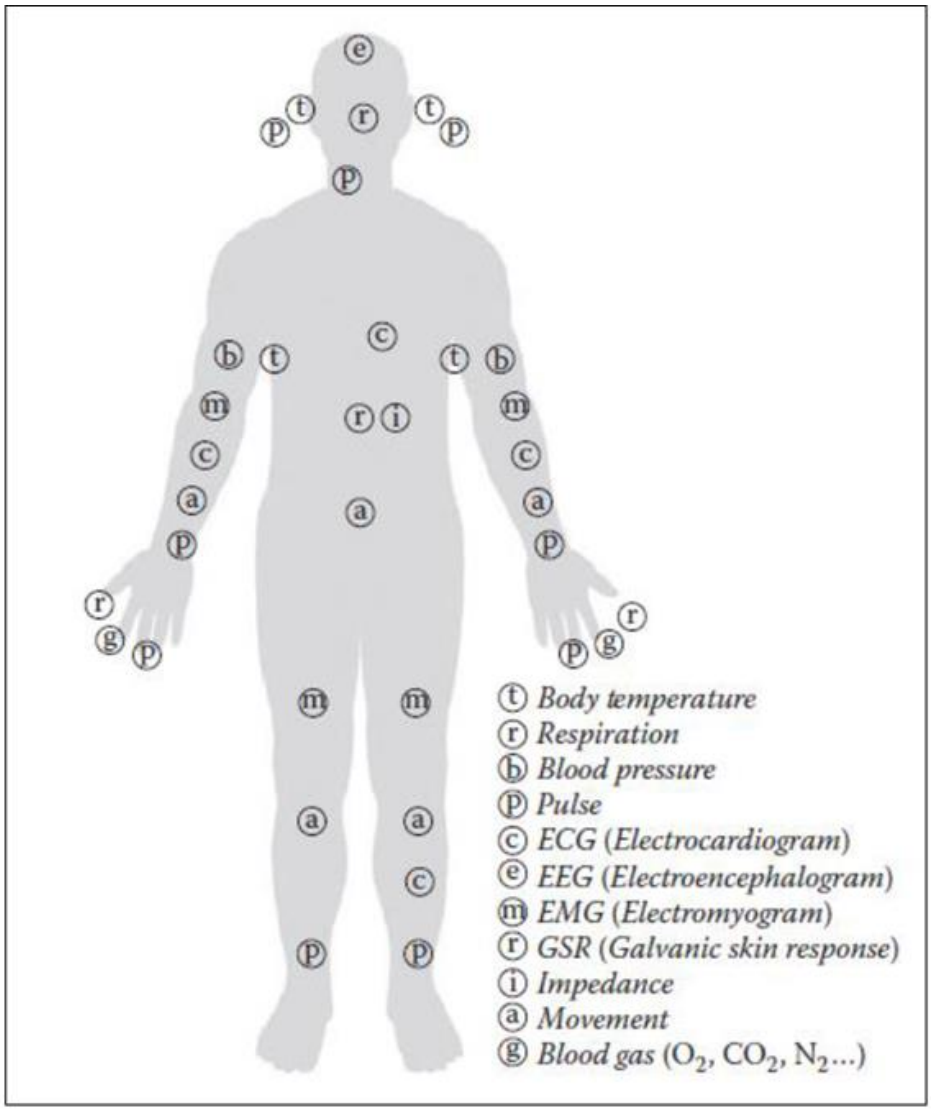


Figure 28: Most important vital signs and the monitoring locations on the body

There is huge variety of sensors producers, but usually produced sensors are not wearable and difficult to be integrated. Therefore, this is one of the goals of the CareWare project. Vital signs (on body) sensors which will be used in project are an accelerometer (movement sensor), breathing rate sensor, body temperature sensor, heart rate sensor, ECG sensor, humidity sensor. All these sensors have alternatives produced by different manufacturers.

Typical ***ECG sensors*** producers are Philips, Nikomedusa, Medline, GaesMedica etc. However, these are electrode-based. Optical sensors have created a growing attention in heart rate monitoring through various applications that can be integrated with wearable gadgets, which include watches, smart phones and fitness equipment. Optical sensors enlarge the opportunities through self-observation through small gadgets for wrist and fingers which is more convenient. However, they are much less accurate than the conventional electrode based sensors. Typically, optical sensors are only used to measure heart rate, oxygen levels and saturation levels.

Heart rate sensors producers are Polar, CooSpo, Genesis etc. Sometimes smart devices with this sensor calculate HR variability. Examples of HR sensors are presented in Figure 29: . This type on

sensor is very popular and serves as component of smart small monitoring system as bracelet or watch and can be easily integrated in smart textile.

Figure 29: Examples of optical heart rate sensors

Accelerometer (inertial sensor), sensors producers are Silicon sensing systems, Microsence, Rieker etc. Examples of accelerometer sensors are presented in Figure 30: . Usually this type on sensor is component of smart small monitoring system as bracelet or watch and together with HR (Hearth rate) or pulse sensors.

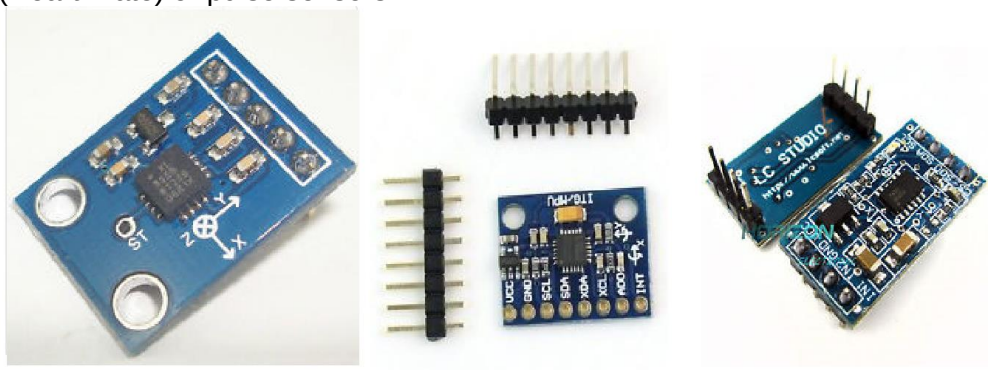


Figure 30: Examples of accelerometer sensors

Skin humidity and body temperature sensors producers are Siemens, Philips, Moritex, Arduino etc. Examples of skin humidity and body temperature sensors are presented in Figure 31: .

Figure 31: Examples of skin humidity and temperature sensors

Breathing rate sensors producers are Motorola, Spire, PCMag etc. Examples and devices of breathing rate sensors are presented in Figure 32: .

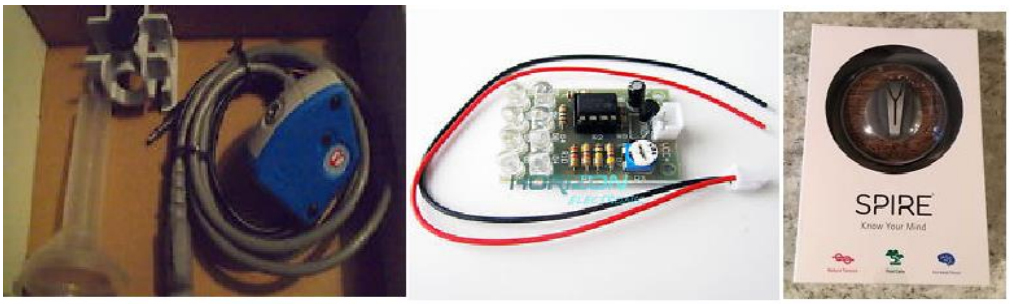


Figure 32: Examples of breathing rate sensors

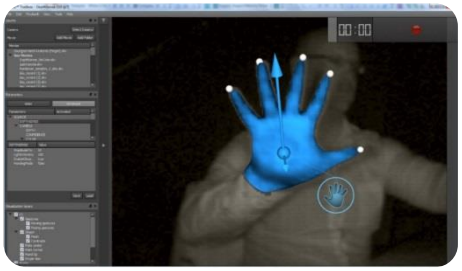
For any wearable sensor for sensing bio-electrical signals one of the main components of the electrode is directly in contact with human skin. Typical commercial gel / hydrogenated electrodes ensure good electrical contact with the skin and bioelectrical signals, but since these electrodes are disposable, they cannot be considered to be glued to the skin for a very long time - it can cause skin irritation reactions.
Alternatively, "dry" electrodes made from electrically conductive material (generally textile) can be proposed. Substrate for this electrodes serve textiles woven of thin metal (Ni and its alloys, Cu, Ti, Al, etc.) in combination with synthetic or natural fibers. However, these fibers can cause skin irritation. Other alternative - electrical conductive synthetic or natural fibers coated with electrically conductive polymers (polyaniline, polypyrrole) or metal layer, using an electrically conductive paint (usually graphite or Ag-based micro particles) silk-screen printing. However, screen-printing method coated textile electrical conductivity sharply decreases or disappears completely for wearing conductive layer mechanical erosion (grinding, bending intense movement at the time) or through chemical and electrochemical corrosion (washing, exposing moisture and perspiration).
In observing of bioelectrical signals for the "dry" the electrodes carbon black, carbon nanotubes modified textile composites can be used. Therefore, one can assume that this objective may be suitable graphite felt obtained graphited-carbonized rayon or polyacrylonitrile fiber base. This fiber is very light and flexible, but also has a large specific surface, thermal, chemical and electrochemical resistance, good electrical conductivity. Therefore, one can assume that it is suitable for textile composites to integrate intelligent clothing bioelectrical signal recording electrodes.

6.2.2 (Optical) Cameras

Depth sensing and gesture recognition are starting to get attention on the high-end ICT markets today. Within the consumer market and especially in the home environment, the smart TV and gestural interface have been introduced successfully.
SoftKinetic, a partner in the CareWare project, is a Brussels, Belgium-based fab-less semiconductor company with the single mission to provide 3D time-of-flight (“TOF”) Sensor Solutions and 3D Time-of-Flight Cameras for building 3D gesture-based interfaces. The Time-of-flight technology is complex but very tuneable in use, because it is based upon the calculation of the duration that a light signal takes between the source of illumination) the light source in the camera’, and the illuminated scene with reflections of the light towards the lens of the camera that illuminates the ToF sensor. This calculation must thus take into account the speed of light, optical interference and the combination into a real/time video signal.
Compared to the structured light solutions, on the market as Microsoft Kinect1, ToF technology can be better tuned towards specific situations. For example, the DepthSense DS325 camera was the first on the market with a range (distance of measurement away from the camera) as close as 10 cm. In 2013 the 3D offering on the market has changed. Only SoftKinetic and PMDtec remain as competitors in Time-of-Flight technology. The other companies, such as Canesta and PrimeSense,

which were on the market when SoftKinetic was launched as a company, have all been acquired. Hence, Softkinetic is currently one of the few players that can satisfactory respond on time and with quality to the emergence of niche '3D Gesture / Natural Interfaces' and having its in house knowledge on the ToF sensors. Complementary, the DepthSense technology is available in several cameras having reached a level of maturity satisfying essential needs the functioning of the different types of uses of 3D Gesture technology. Nevertheless, the diversity of applications, and the specific needs of such applications, including interoperability, requires the continuation and intensification of the research and developments efforts. Hence, we intend to orient the future work as to enrich the basic features of the current SDK with innovative features identified as complementary and/or key to the diffusion of the SoftKinetic technology, such as wear ability of the solution.

The DS325 camera

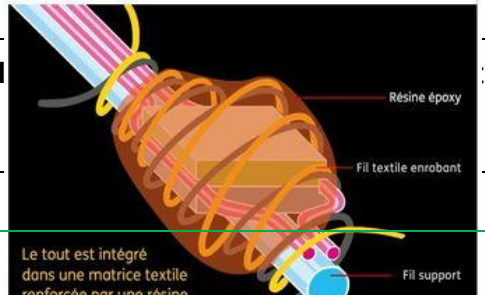


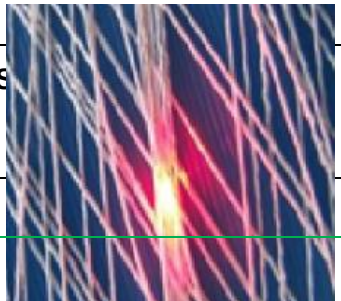
The SKS close range middleware

6.3 (ELECTRONIC) TEXTILES

In many cases, there are sensors that are integrated into the textile rather than the textile itself being the sensor. Whereas a whole range of sensors and microelectronics are available on the market (see above), sensors/electronics that can be designed on or into the textile can be:

- Antennas: where a large area ensures a good communication between the hub and the textile. The antenna can be made of conductive yarns or simply be printed on the textile.
- Touch sensors (capacitance): where the sensor is a passive printed capacitor. Using screen printing, there is a large variety in design where the parallel plates of the capacitor can be separated using a dielectric layer. This requires the printing of multiple layers on top of each other.
- Electroluminescence: while LEDs have to be incorporated as a whole into a textile, flexible electroluminescent films can be printed onto a textile. This requires a functional design where several layers (conductive-dielectric-phosphorescent-transparent conductive) need to be printed on top of each other.
- Heat able textiles: this is a simple design where a conductive yarn or printed conductive circuit functions as a resistor that will heat when sufficient current is applied.
- Spun-out from a European FP7 programme, the company Primo1D (http://primo1d.com/) developed yarns in which sensors are integrated. The E-thread contains either LED, RFID or other sensors that are incorporated in a way that they are barely visible.





left: Schematic view of the primo1D yarn with a supportive filament (blue), two conductive threads (pink) an encapsulating filament (yellow) and electronic components embedded in an epoxy resin. Right: example of a functional LED module in the yarn.

Whether it is to integrate electronic units into a textile or making a sensor on the textile, there is the need for conductive materials. Using a functional design, yarns can be woven, embroidered or knitted into the textile and conductive tracts can be printed on the fabric. Depending on the design, the materials will have different requirements. Underneath, different textile building blocks for smart textiles are listed:

Electrically conductive yarns:

There are many different conductive yarns. These are mainly metallic yarns. For certain applications, the metallic yarn can be coated with a protective layer, or can be twisted with a conventional yarn. On the other hand there are also conductive coatings which can be applied to yarns, usually based on silver or carbon particles. Carbon fibres are also available, but are usually intended for antistatic applications. The main properties will depend on the resistivity of the yarn, which is highly correlated to the material, thickness and length. Conductive yarns are used for weaving, knitting or embroidery towards a functional design in a smart textile.

- Swicofil conductive yarns and threads http://www.swicofil.com/textile.html
- Bekaert/Bekintex conductive yarns http://www.bekaert.com/en/products/basic-materials/textile/stainless-steel-fibers-for-anti-static-textiles-bekinox
- Ohmatex conductive elastics http://www.ohmatex.dk/
- Shieldex conductive yarns http://www.statex.biz/index.php/en/
- Amberstrand conductive yarns http://www.metalcladfibers.com/
- Elitex conductive yarns http://www.imbut.de/smart-textiles/

Screen printing:

Screen printing is the technique where a pattern or design is applied onto a flat surface. Using different layers and designs, smart textiles can be developed. However, certain problems must be addressed. For example, screen prints need a flat surface, and in many cases a flat (transfer) coating needs to be used in order to make the rough surface of a textile suitable for printing. Alternatively the electronic can be printed on a transfer paper which can subsequently be transferred onto the textile using a TPU. Another problem lays in the stretch ability of textiles. Many rigid inks are available for screen printing of electronics onto films, but only a limited amount of stretchable conductive inks are available:

- Henkel WIK20486-56A, flexible and stretchable silver ink for screen printing http://www.henkel-adhesives.com/conductive-inks-coatings-27433.htm
- Dupont PE872, flexible and stretchable silver ink for screen printing (newest generation Dupont PE873 en PE874 currently only available for the American market) http://www.dupont.com/products-and-services/electronic-electrical-materials/printed-electronics.html
- Heraeus Clevios SV4, conductive water borne conductive polymer (PEDOT-PSS) for screen printing http://www.heraeus-clevios.com/en/home/clevios-homepage.aspx
- Agfa Gevaert Orgacon series, conductive water borne polymer (PEDOT-PSS) for screen printing http://www.agfa.com/orgacon

Connectors:

Incorporating electronically conductive yarns or components can be cumbersome, as the connection with other electronic compounds or batteries requires special assembly. This on the one hand makes confection more expensive, but it is often also a fragile piece of the smart textile. The connectors are the place where rigid pieces of an electronic chip or sensor meets the flexible textile. There are some clips and glues available that are often used to integrate electronics onto a textile:

- Ohmatex flexible clips http://www.ohmatex.dk/
- Conductive TPU, e.g. plasticyl http://www.nanocyl.com/
- Henkel conductive adhesives http://www.henkel-adhesives.com/conductive-inks-coatings-27433.htm
- Sparkfun https://www.sparkfun.com

6.4 OFF-BODY COMMUNICATION (GATEWAYS)

Gateways:
A Gateway allows making data transfer from one point to another.
There are two types of Gateway:

- The "local" Gateway that collect sensor data then transfer outward of the user, for example to a Smartphone which in this case can serve as a local GUI with the controls of the gateway and data visualization.
- The "external" gateway for transmitting data from a private network around the user to other horizons such as the cloud.

In this case, there are various types of GW, from Smartphone that can serve as a gateway or other boxes that adds "almost" infinite interfaces to enable to open to all types of application for data exploitation. For example, Garmin watches have a USB interface that allows the transfer of data after a user session to analyse the user's performance.

OFF-Body Communications:

The OFF-Body communications can be of any kind.
In existing products in the market, there are often standardized communication elements such as Bluetooth, BLE or ANT allowing in much of connecting to a smartphone.
Now, the market tends to a large opening of these communications to enable centralization of data to the cloud so they can then be processed, analysed and stored.
There are 2 main types of possible communications:

- Communications called "wired", for examples:
  - The USB allows the connection posteriori,
  - The Ethernet to enable to connect the GW to an existing network,
- Communications called "wireless", for examples:
  - The GPRS allowing the GW to be autonomous and data transfer,
  - The Wi-Fi in order to connect to an existing network without wired constraint,
  - The LORA, to transfer small amounts of data over a long distance.

Overall, the choice of the communication must be made according to user needs and respecting the compromise between the amount of data to transfer, the need of gateway autonomy and the distances to cover for the transfer.

7. STATE OF THE ART IN ALGORITHMS AND DATA PROCESSING (FOR BODY MONITORING)

The increasing variety of sensors, technical possibilities and their utilizations in human health status monitoring and evaluation, together with a significant increase in data mining methods, algorithms and corresponding software demands a significant development in algorithms and data processing for body monitoring. Interpreting the data collected by the different sensors worn by a user (or available in the user's neighbourhood) requires first fusing and synchronizing the collected data, taking into account that it consists of different types of data from a disparate set of sensors, and that different sensors can sense and produce data at different rates. This might also require identifying and filtering out not relevant enough sensor signals.

Next, by building and maintaining from this flow of data a consistent and up-to-date model of the user's current context, encompassing both the user's physiological state and the user's environment, and through reasoning on top of this model, feedback and recommendations adapted to this context can be provided to users. While doing this, similar situations from the same user or from other users in comparable situations might be taken into account to find and suggest advices that were effective in other similar contexts and to detect anomalies.

Finally, services built on top of the data collected by wearables "need to invest in immediacy by providing useful information, ideally in real time, so we can optimize our wealth of data into action"[6]. This requires efficient (near) real-time data storage and processing.

The following sections elaborate on the state-of-the art in these different areas.

7.1 DATA UNIFICATION AND SEMANTIC REASONING

Data unification is concerned with combining data from different types, levels and sources in such a way that they are made compatible and comparable, and thus useful for further processing. In the past decades, data interoperability and data integration have been extensively explored research topics, mainly focused on syntactic and structural heterogeneity. A major remaining challenge is semantic heterogeneity, e.g. differences in the interpretation of the meaning of data. A promising approach is the use of a semantic model, which is, in general, a way of formally representing knowledge about a particular domain, thereby defining a controlled vocabulary. Ontologies are the most popular form of semantic models, but other forms exist. Semantic models are used for various purposes and in many domains. They have been used most successfully for data integration purposes in the life sciences domain[7], where the need for controlled vocabularies is high, due to the huge amounts of experimental data that are generated and the wide variation in terminology that is used. In recent years, they are also increasingly used in the ubiquitous computing domain.

Several tools exist that support both development of ontologies and their integration into decision support applications. Protégé[8] is a very popular ontology editor. SPARQL[9] is a query language for RDF[10]. Jena[11] is a framework for building semantic applications, including a reasoning engine.

[6] http://mashable.com/2014/01/26/fitness-trackers-real-time-data/
[7] http://www.geneontology.org/
[8] http://protege.stanford.edu/
[9] https://www.w3.org/TR/sparql11-query/
[10] https://www.w3.org/TR/rdf11-concepts/
[11] https://jena.apache.org/

7.2 TEMPORAL DATA MODELING

Temporal data modelling consists in retrieving recurring patterns in sequential data. When this data is discrete (e.g. the point of interest where a user is, the activity that a user is performing, user's state such that "has fever") temporal data mining can retrieve recurring successions of states that describe expected behaviour. When the data is continuous (e.g. heart rate and weight measurements) temporal data mining (also referred to as *time series analysis*) can discover trends and deviations from those trends.

7.2.1 Discrete data

The Apriori algorithm (Agrawal et al. 1993, Agrawal et al. 1994) aims to discover "association rules between items in a large database", i.e. a combination of items, by assuming that "any subset of a large item set must be large". The Apriori algorithm was born in the domain of transaction logs, where the goal was to find sets of items that are bought together.
Temporal Association Rules (TAR) (Xinfen 1998) are an extension of the Apriori association rules by introducing (among others) a temporal component. Specifically, TARs can constrain the time over which item sets are spread out.
SPMF (Sequential Pattern Mining Framework) is a framework that hosts, among other algorithms, the Apriori algorithm and several other association rules algorithms. In addition, it also allows the user to perform clustering (k-means, hierarchical clustering) and classification (ID3) tasks. ProM (van der Aalst 2011) is a framework for performing Process Mining algorithms. Whereas SPFM focuses on large item sets and association rules, ProM targets the extraction of knowledge from process flows.

7.2.2 Continuous data

Moving average (MA) is a technique that can be traced back to the moving summation of Slutzky (Slutzky 1937) and is frequently used when volatile data needs to be smoothed to get an insight in the trends that are hidden in the data. As an example, consider continuous heart rate measurements that might fluctuate either due to the activities performed by a user or due to the accuracy of the sensing device. A moving average will smooth out these fluctuations and highlight longer term trends by calculating an average over a predefined time window.
On the other hand, autoregressive models look at previously observed values in order to infer a trend and be able to predict future values.

7.3 PROBABILISTIC MODELING

Whereas the modelling methods above consider the values of variables and try to detect patterns or functions through these values, probabilistic modelling approaches do not consider values as such, but rather calculate the probability that a possible future state will follow on the present state. This idea lies at the core of a Markov Chain, and Markov Chains are what brings the following methodologies together.
Perhaps one of the oldest state-based modelling methodologies, while still frequently used today, is the Kalman Filter (Kalman 1960). Its main advantage is the fact that it can smooth out – a little bit like auto regression, but then for complex states – noise or errors in the observed state by considering its probability with respect to the previous state. In the Kalman Filter, a single state is represented as a vector (of numbers). When a state is observed, the vector that represents that state is compared to a predicted vector that was based on the previous state. The observed state is then 'updated' by averaging the observed values and the predicted values.
A Bayesian Network differs from a Kalman Filter in the sense that it does not interpret the idea of a Markov Chain temporally, but causally. The idea is that the state of a certain variable can be related causally to the state of another variable, and that this causality can be grasped by a probability. The

textbook example is fraud detection, where the state *fraud* is highly probable – and therefore caused by – in combination with the states *buying gas* and *buying jewellery*.
Dynamic Bayesian Networks (DBNs) put the temporal dimension back into Bayesian Networks. Like a *Hidden Markov Model*, DBNs put several (static) Bayesian Networks (that represent a specific point in time) after each other and assume that the most probable configuration of the future Bayesian Network can be inferred from the current Bayesian Network.
These powerful probabilistic modelling approaches can all be used to make forecasts about future states of the reality that they describe.

7.4 SIMILARITY-BASED MODELING

Next to temporal data modelling and probabilistic modelling, it is also possible to consider similarity-based models, where the similarity between instances is used, e.g. for user profiling. An archetype of a category, e.g. a certain type of user, is constructed by identifying a number of features that this category exhibits. Consider a user profile for a patient that is recovering well from an operation; features for this profile could be “two consecutive days without pain” and “blood pressure is within normal range”.
At the heart of similarity based models lie (dis)similarity metrics that quantify how much overlap there is between the features of any given instance and an archetype. Several metrics exist, and one could distinguish between metrics that deal with discrete features, such as the Jaccard coefficient, versus metrics that can deal with numeric features. These latter metrics can again be divided in two groups. Both groups consider the features as dimensions in a geometric space. In the first group, dissimilarity between instances is defined as the geometric distance between the instances. Typical metrics are here the Euclidean distance or any Minkowski distance. The second group considers not the position of the instances in the space, but rather the vectors between the instances and the origin of the space. Similarity between the instances can then be defined by, e.g. the angle between the vectors. A typical example for such metrics is the cosine similarity metric.
Once the (dis)similarity between instances is established, clustering and classification algorithms can be applied. Clustering algorithms typically try to minimize the (average) distance between instances within the cluster and maximize the (average) distance with other clusters. Only a certain subset of classification algorithms is based on dissimilarity between instances. The most well-known of this subset is k-Nearest Neighbours, where the majority class of the k most similar instances is assigned to the instance that needs to be classified.

7.5 SCALABLE STREAM PROCESSING AND COMPLEX EVENT PROCESSING

Stream-based processing systems combine high amounts of data from multiple sources, arriving at varying rates, and process this data immediately.

- S4[12] is a general-purpose, distributed, scalable, fault-tolerant, pluggable platform allowing development of applications for processing continuous, unbounded streams of data.
- Storm[13] is a scalable, fault-tolerant and distributed real-time computation system that makes it easy to reliably process unbounded streams of data.
- Spark Streaming[14] is an extension of Spark[15] that enables scalable, high-throughput, fault-tolerant stream processing of data streams at a high-level abstraction.

[12] http://incubator.apache.org/s4/
[13] https://storm.apache.org/
[14] https://spark.apache.org/streaming/

On the other hand, Complex Event Processing (CEP) platforms offer higher-level and dedicated support for inferring patterns that suggest more complicated circumstances, aiming to identify meaningful events (e.g. anomalies, threats etc.).

- Drools[16] is a business rules management system able to understand and handle events or stream of events, detect relevant patterns and take appropriate actions based on the patterns detected.
- StreamBase CEP[17] a complex event processing system that provides rapid application development via a graphical event-flow language and integration with streaming and historical data.
- Esper[18] is a complex event processing and event series analysis component providing rapid development of applications that process large volumes of historical or real-time incoming messages or events.

[15] https://spark.apache.org/
[16] http://www.drools.org/
[17] http://www.streambase.com/
[18] http://www.espertech.com/esper/

8. HEALTH PLATFORM SOLUTIONS

8.1 INTRODUCTION HEALTHCARE PLATFORMS:

More and more applications that use real world data are requiring real-life control of real-world devices. Remote access of both sensors and data are finding their way to commercial applications in healthcare or smart cities. The volume of data that is generated and processed locally becomes in this way very costly. On the other side, there are also more and more devices that need to connect to each other with heterogeneous operating systems or data ontologies. This requires pre-defined protocols and interfaces that allow various subsystems to work together. The last years, scalable cloud storage and cloud solutions have been introduced to tackle challenges such as data interoperability, security, storage and communication. [19]

When assessing existing technical frameworks, most platforms apply similar characteristics in terms of data storage, support for web technologies and availability of REST API. There is however a difference in some commercial systems that are closed source, meaning that not all APIs are open for commercial usage. On the other side the open source platforms are easy to be used for generic solutions using standardised interfaces and data exchange formats.

When selecting the platform that will be used, one of the characteristics is the data interchange format. There will be a difference in efficiency of data transportation whether they are textual data interchange formats (serialised data) or standardized binary data interchange formats (requiring less bandwidth).

8.2 COMMERCIALLY AVAILABLE CLOUD SYSTEMS IN HEALTHCARE:

There are more and more healthcare platforms available on the market for storing, managing and exploiting health data, focussing on both consumers and professionals. Hereby, a short overview of some of such systems.

8.2.1 Health information platforms

Health information platforms focus on storing and managing patient health data.

8.2.1.1 Apple HealthKit

Description

HealthKit is a central platform for health information. You can also see diagnoses, results of lab tests, store diagnoses and medical examinations.

Functionality:

- The app gives an easy-to-read dashboard for any fitness and health data. As the functionalities are related to third party applications, they go very broad. From medication management,

[19] Vincent et al. (2014), Towards a Generic Cloud-based Sensor Data Management Platform: A Survey and Conceptual Architecture. SENSORCOMM 2014

symptom tracker, physical activity tracking, heart rate measurements, sleep measurements to glucose monitoring.

- An interesting feature on Apple Healthkit is the interaction with medical record. This allows merging data from medical records on patient reported outcome data or data retrieved via wearable sensors or medical devices. There is no real-time visualisation of data possible; data is only visible after syncing. The following data is accessible:
    - Active Calories, Biotin, Blood Alcohol Content, Blood Glucose, Blood Pressure Diastolic, Blood Pressure Systolic, Body Fat Percent, Body Mass Index, Body Temperature, Caffeine, Calcium, Carbohydrates, Chloride, Chromium, Copper, Cycling Distance, Dietary Calories, Dietary Cholesterol, Electro dermal Activity, Fibber, Flights Climbed, Folate, Forced Expiratory Volume, Forced Vital Capacity, Heart Rate, Height, Inhaler Usage, Iodine, Iron, Lean Body Mass, Magnesium, Manganese, Molybdenum, Monounsaturated Fat, Niacin, Nike Fuel, Number of Times Fallen, Oxygen Saturation, Pantothenic Acid, Peak Expiratory Flow Rate, Peripheral Perfusion Index, Phosphorus, Polyunsaturated Fat, Potassium, Protein, Respiratory Rate, Resting Calories, Riboflavin, Saturated Fat, Selenium, Sleep Analysis Asleep, Sleep Analysis In Bed, Sodium, Steps, Sugar, Thiamine, Total Fat, Vitamin A, Vitamin B12, Vitamin B6, Vitamin C, Vitamin D, Vitamin E, Vitamin K, Walking + Running Distance, Weight, Workouts, Zinc

Third parties:
Apple Healthkit works with third party applications to enrich the data and merge it in one dashboard. API's are available for technology providers to exchange data.

Target Audience
Apple Healthkit targets consumers (owners of apple devices) and partnership with health technology solutions.

8.2.1.2 Samsung S Health platform-SAMI

Description
Samsung Digital Health helps application developers and healthcare providers thrive in an open environment that connects sensors, devices and partner services. Users can experience various health and fitness services through Samsung Digital Health.

Features
S Health is an engaging app for fitness and wellbeing that keeps track of users' health data. Data from S Health can be shared with other applications using Samsung Digital Health SDK. The SDK provides secure access to health data with applicable data types, and it allows sharing health data between applications with user's consent. The application data could be visualized in a form of tile in the main dashboard of S Health.

Third parties
S Health partners with applications that run on Android to read and write data to the S Health platform.

Target Audience
Consumers and B2B applications working on Android.

8.2.1.3 Qualcomm Life/2net

Description

Qualcomm Life's main product is 2Net, a home gateway device that collects and encrypts biometric data coming off a patient's medical devices. Once the data is collected in the gateway device, it's sent to a cloud backend for doctors or medical institutions to access. This allows doctors to better keep track of patients when they are at home.

- The 2net Platform leverages network operations, European data centers and cloud-based services designed to allow integrated medical devices to securely and reliably share data with approved healthcare providers, payers and patients. The 2net Platform is medical grade and ISO 13485 certified, meaning it aligns with the quality requirements of international regulatory agencies that oversee the healthcare industry.

Features

- **Data Acquisition**: Medical device data is obtained from a patient's device through several potential gateways, such as the 2net Hub, 2net Mobile on a mobile phone or tablet, a cellular-enabled medical device or a partner service application. Qualcomm Life has established pathways for each gateway to extract data from the medical device and input it into the 2net Platform's European data centre.
- **Data Transmission**: Once the data is acquired from the medical device, it is transferred utilising redundant, private connections between the wireless carriers and the 2net Platform's data centre.
- **Data Storage/Access:** After the 2net Platform has received the transmission, medical device data is transferred to the manufacturers' interface of choice for the patient, physicians, payers, or other partners to access. The tools in our Network Operations Centers or NOCs proactively monitor and manage the network to provide reliable data transfer.

Third parties

Open to third party integrations

Target Audience

B2B audience

8.2.1.4 Microsoft HealthVault

Description

Microsoft HealthVault is a web-based platform from Microsoft to store and maintain health and fitness information. A HealthVault record stores an individual's health information. Access to a record is through a HealthVault account, which may be authorized to access records for multiple individuals. An individual interacts with their HealthVault record through the HealthVault site, or, more typically, through an application that talks to the HealthVault platform. When an individual first uses a HealthVault application, they are asked to authorize the application to access a specific set of data types, and those data types are the only ones the application can use. An individual can also share a part (some data types) or the whole of their health record with another interested individual such as a doctor, a spouse, a parent, etc.

Features

HealthVault Connection Centre allows health and fitness data to be transferred from devices (such as heart rate watches, blood pressure monitors and the Withings Wi-Fi body scale) into an individual's HealthVault record. It can also be used to find and download drivers for medical devices. In 2014 Microsoft introduced the Microsoft Band a fitness band that is powered by Microsoft Health, a service

that supports the Microsoft HealthVault for aggregation and integration of different services such as MyFitnessPal.

- HealthVault supports storage of DICOM based medical imaging. Consumers can upload and download medical imaging DVD through HealthVault connection centre. Third parties can also upload and download medical imaging to/from HealthVault, for example Candelis. In addition, there has been plethora of HealthVault medical imaging viewers released by the third party to connect to HealthVault even on mobile phones.
- HealthVault supports a number of exchange formats including industry standards such as the Continuity of Care Document and the Continuity of Care Record. Support for industry standards makes it possible to integrate with much personal health record solutions.

Third party integration
Health Vault is open to third party devices and applications to store or read data.

Target Audience
Consumers and B2B partners, including hospital EHR systems.

8.2.1.5 Google Fit

Description
Google Fit is the simpler, less medical-focused version of the Apple HealthKit, utilising the inertial sensors in a smartphone to work out when one is walking, jogging or cycling. It also works with Android Wear and the web.

Features
Currently it accesses the accelerometer / light sensors from the phone/smart watch to measure physical activity or heart rate information. Google Fit allows wearable devices that measures data like steps or heart rate to interface with Google's cloud-based services, and become part of the Google Fit ecosystem. Extracted features are:

- height, weight,
- calories consumed,
- heart rate,
- BMR,
- body fat percentage

Third party integration
Google is working on access by third party applications to enrich the data. Google Fit will aggregate data through open APIs to allow apps to share information, and will announce partnerships with wearable device makers, but currently this is still under construction.

Target Audience
Consumers. It does not focus that much on medical data or partners in that field.

8.2.2 Health Management Platforms

Health Management Platforms focus on managing and exploiting patient health data.

8.2.2.1 Orion Health

Orion Health provides a medical-focused health management platform aimed at:

- aggregating and storing all forms of patient clinical data, giving access to predictive modelling tools that identify and stratify risks in a population and drive rapid decision-making,
- providing dedicated tools to enable patient-centric care through better decision-making and fully-informed actions,
- achieving rapid interoperability between healthcare systems, enabling connected solutions in less time and at a lower cost,
- providing reliable and protected communication between patients, healthcare providers and organisations across mobile, desktop and electronic medical record (EMR) systems, allowing users anywhere to quickly send accurate patient information to other healthcare providers or even to the patients themselves

Orion Health products provide healthcare organisations with the tools needed to aggregate all health determinants and leverage that information to improve quality of care and clinical outcomes within the hospital and across the entire community. It relies on standards such HL7 FHIR capabilities, to help implement interoperability among the various health management systems that are deployed from the government level and insurer levels down to the hospital level and the individual patients.

Orion provides pre-configured solutions to accelerate the deployment of complex health management solutions. The process workflows within the organisation can be customised either before go-live or post go-live to to meet evolving clinical and administrative needs. Intuitive man-machine interfaces allow the solutions to be rolled out with minimal end-user training.

8.2.2.2 Tactio Health Group

Tactio Health Group provides a white-label Mobile Remote Patient Monitoring platform that is available as a complete end-to-end system and as a platform for innovative healthcare application developers to provide digital coaching for patients.

On top of that platform, Tactio Health Group provides several pre-configured applications including:

- patient monitoring platform for hospital or clinics providing the clinicians with efficient remote care tools,
- remote patient applications for delivering home health tracking of body weight, blood pressure, heart rate, diabetes, cholesterol and more from manual data entry or automated e-health synchronisation from connected health devices.

8.2.2.3 Santech

Santech have built a software suite aimed at accelerating and fostering the development of m-health/e-health solutions focusing on the end-user (patient) and the ability to create mash-up applications, that is to say solutions that combine contents and services provided by technically and functionally heterogeneous third-party solutions. This software suite includes the following building blocks:

1. **A UI framework** (Santech Studio) for the development and execution of the user interface software. This framework is used to manage the end-user interactions on the one-hand and to exchange relevant data with the application server on the other hand.

2. **A parameterizable application server** (Santech Engine) for the definition of the application semantics and behavior, including the definition, the parameterization tools and the access web-services for a range of generic objects (also called meta-objects), with a strong focus on the management of smart workflows for describing customized and contextualized processes for improving one's health and well-being.

3. **A connector framework** (Santech Connect) for implementing interoperability between the application server and repositories or third party health services in order to build a composite application. Connectors can be linked to specific objects in order to implement built-in data synchronization between several connected health applications.

On top of this software suite, Santech provides pre-configured applications in two domains:

1. AEM (Aidés et Moi meaning "my caregivers and me") is a core application dedicated to the coordination of caregivers for an elderly. The core application provides the following functionalities:

2. MVP (Mieux Vaut Prévenir meaning: "prevention is better") is a core application providing a personal health notebook on mobile, including user's health profile management, health recommendations management, contextualized access to health data sheets, etc.

8.2.3 BENCHMARKING WITH CAREWARE

The Careware project focuses primarily on the architecture to capture data in real life, based of novel sensor technologies that are being developed during this project and the algorithms that will be developed to quantity the user's health status. It is aimed at defining an integrated approach and an open architecture in order to quantify the quality of life. In this regard, Careware is very end-user focused.

Hence, the Careware platform can be seen as a merger of two platforms:

- a wearable platform including integrated sensors and equipment used to capture and store health data information,
- an end-user health data management platform that is used to interconnect and to provide management tools for any actor in the patient eco-system, including the end-user himself.

Most existing platforms (except Santech) are based on the implementation of standardized data protocols for data exchange between the patient and the medical staff or between the members of the medical staff. In other words, they are more focused on disease management than quality of life.

The most innovative part of Careware relies on the definition of a global architecture of the eco-system rather than the selection of a particular platform technology. In this respect, the Careware project is aimed at providing insight on the optimal split of functionalities between all the components of the eco-system and providing the requirements for the health management platform in order to support the end-user quality of life, including his health and well-being.

9. CONCLUSIONS

In this deliverable, an extensive overview of different 'commercial' systems is given and reviewed/discussed with respect to the 'to-be-developed' Careware system(s). From the benchmarking table, one could see that the available systems typically use modules which are not integrated into the textile. These are usually straps that can cause comfort issues and are not washable. While in the CareWare, the project partners aim to work to a fully integrated sensor in the textile, that is washable, flexible and moderately stretchable in a non-stigmatising way. Specifically for the patient-monitoring use case (UC1); although there are many hearth rate monitors, breath rate and accelerometers on the market, little of them are provided in a way of modular units that can be integrated by a confectioner into a textile. Therefore, the current examples are difficult to easily implement to hospitals. For this use case, we aim to develop modular units that can be integrated into different hospital garments (and sizes) for the patient.

The increasing variety of sensors, technical possibilities and their utilizations in human health status monitoring and evaluation, together with a significant increase in data mining methods, algorithms and corresponding software demands a significant development in algorithms and data processing for body monitoring. It is clear that innovations in both domains are still necessary to bring the system technology solutions closer to the end-user expectations/needs.

Most currently-available health platform solutions existing platforms (with the exception of the Santech platform, which is part of the CareWare project) are based on the implementation of standardized data protocols for data exchange between the patient and the medical staff or between the members of the medical staff. In other words, they are more focused on disease management than quality of life.

The most innovative part of Careware relies on the definition of a global architecture of the eco-system rather than the selection of a particular platform technology. In this respect, the Careware project is aimed at providing insight on the optimal split of functionalities between all the components of the eco-system and providing the requirements for the health management platform in order to support the end-user quality of life, including his health and well-being.