This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No 826304

THEME [SC1-DTH-03-2018]

Adaptive smart working and living environments supporting active and healthy ageing

„Personalized Body Sensor Networks with Built-In Intelligence for Real-Time Risk Assessment and Coaching of Ageing workers, in all types of working and living environments"

Project Reference No	826304
Deliverable	D2.1 Kinetic, Physiological and Environmental Sensors
Workpackage	WP2: Connected Loosely Coupled Smart Sensors
Nature	D (Deliverable)
Dissemination Level	RP (Restricted to other program participants (including Commission Services))
Date	20/12/2019
Status	Final Version
Editor(s)	Claus Pribbernow (IAW)
Document Description	This deliverable presents the selection of kinetic, physiological and environmental sensors, driven by user requirements defined in D1.1 and medical requirements defined in D1.3. The sensor implementation is aligned to the technical requirements defined in System Architecture and Technical Specifications D1.5 and follows the guidelines to be integration friendly into the BIONIC BSN.

CONTENTS

LIST OF TABLES

List of Figures

Table 1: List of Abbreviations

Term / Abbreviation	Definition
BSN	Body Sensor Network
SSN	Smart Sensor Node
mHub	Micro Sensor Hub
BLE	Bluetooth Low Energy
BLE Node	Smart Sensor Node with a BLE-MCU host
Sensor Hub	Sub System which host multiple SSN
SPINAL	SPI Network Application Layer
SPI	Serial peripheral Interface protocol on physical layer
IMU	Inertial Motion Sensor
Haptic Hub	Sensor Hub with vibration motor
OWAS	Ovako Working posture Assessment System
NFMI	Near field magnetic induction

1 INTRODUCTION

1.1 PURPOSE OF THE DOCUMENT

This deliverable presents the selection and implementation of the kinetic, physiological and environmental sensors to be used by the BIONIC Body Sensor Network (BSN).

A sensor is a device or subsystem whose purpose is to detect events or changes in its environment and provide the information to other electronics. In the document we will focus to the relevant sensors of type:

- Kinematic/kinetic sensors – as an electronic device that measures and reports a body's specific force, angular rate, and orientation of the body, using a combination of accelerometers, gyroscopes, magnetometers and pressure insoles
- Physiological sensors – as an electronic device that measures the condition occurring from normal body function, e.g. respiration
- Environmental sensor – as an electronic device that measures the environmental condition of a human and specifically of a worker

The BIONIC sensor and sensor selection obey requirements categories as listed:

- User defined
- Medical
- System and functional
- Technical
- Electrical
- Mechanical

For the BIONIC system, the sensor applications will be defined by the end user requirements (D1.1), the medical requirements (D1.3) and the overall system architecture and technical specification (D1.5). The document will outline the specific sensor requirements, the implementation and the technical specification of the selected sensors.

1.2 BIONIC SYSTEM DEFINITION

BIONIC will be a holistic, unobtrusive, autonomous and privacy preserving platform for real-time risk alerting and continuous persuasive coaching, enabling the design of workplace interventions adapted to the needs and fitness levels of specific ageing workforce. Gamification strategies adapted to the needs and wishes of the elderly workers will ensure optimal engagement for prevention and self-management of musculoskeletal health in any working/living environment. BIONIC will integrate sensor modules in multi-purpose, configurable Body Sensor Networks (BSNs) introducing key enablers of user acceptance based on value, comfort, confidence and trust.

The key aspects of BIONIC system should include:

- Holistic, and unobtrusive Body Sensor Networks tightly integrated in a large range of sportswear, work wear, and PPE.
- Real-time intelligent sensor data fusion and analysis at the edge (AI on a chip).
- High focus on user Data Management, Analysis, Presentation and Protection.

- Kinematic and Biomechanical Models for Age Adapted Ergonomic Risk Assessment and Workplace Analysis.
- Gamified User Coaching and User Interaction.

1.3 BSN Overview

This section will provide an overview of the Body Sensor Network architecture to understand the context of the Sensors, its requirements and implementation options.

The full body sensor network consists of a locally distributed, serial wired network of smart sensor nodes connected to a Sensor Hub which acquire the sensor data from the nodes, pre-process and fuse the sensor data in real-time and provide the results to an Application Hub. The system is built in a modular manner to allow scalable and heterogeneous BSN implementations.

The smart sensor node has two main functions to serve. It needs to provide the communication interface in the BSN for the serial point to point communication and it must run the sensor application of the node. The data from the sensor application will be embed into a serial data protocol (SPINAL) which runs on each node in the BSN. This packet based, serial data protocol is based on the SPI physical layer and add one layer above the network application layer which configure, control the network and embed the sensor data in its data payload.

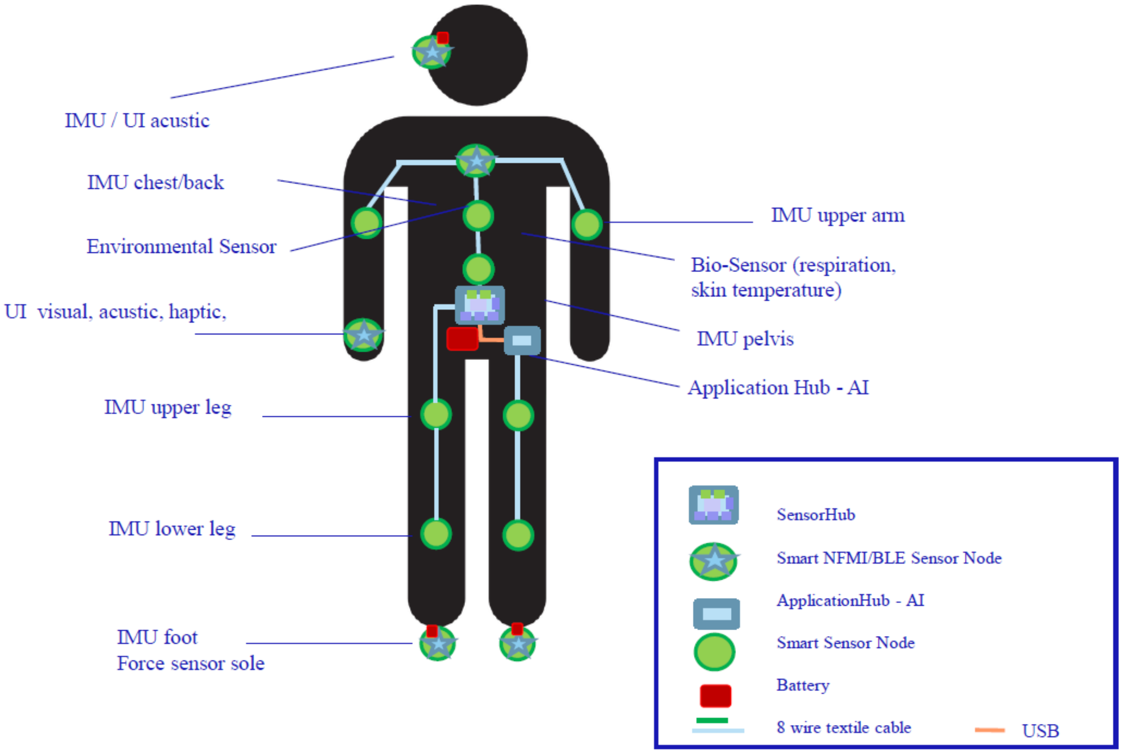

Figure 1: BSN architecture within a heterogeneous implementation

1.4 STRUCTURE OF THE DOCUMENT

This document is structured as follows:

- The requirements section presents the user-defined, medical and system requirement of the sensor which leads to the sensor selection
- The sensor selection based on requirements and user centric questionnaires
- The implementation section includes the specific sensors and their brief technical specification

2 Sensor Requirements

This chapter will document the requirements on the Sensor in the context of the overall BSN developed to serve the BIONIC use cases. It will list the set of requirements to support the sensor selection.

2.1 User defined Requirements

The D1.1 End User requirements include both the functional and non-functional aspects (usability, ergonomics) that must be considered when designing the different elements of BIONIC.
The requirements have been grouped into categories and below you will find a summary table of the functional and non-functional aspects of the Sensors (SE), including type of sensors (ST) which are relevant to the selection of the kinematic, kinetic, physiological and environmental sensors.

Code	Type	Requirement name	Description
SE_01	**F**	Sensors will be loosely integrated into everyday or work clothing (or PPE)	One of the research topics during the project will be to investigate the feasibility of obtaining valid and reliable kinematics using loosely coupled sensors.
SE_02	**F**	BSN will have a minimum autonomy of 8 hours	BSN should have enough autonomy to operate at least for a standard working shift (8 hours)
SE_03	**F**	Sensors actuators will provide feedback to the user	Feedback will be done via smartwatch or by Haptic Hub. Feedback from sensors can be: acoustic, haptic or visual.
SE_04	**F**	BSN will include an integration of specific developed sensors and existing solutions	BSN will integrate existing commercial wearables (e.g. a smartwatch), body-part specific modules and/or specifically developed sensors
SE_05	**NF**	Size and design of the system will be adapted to the anthropometric characteristics of users	*Details at section D1.1* ***Fehler! Verweisquelle konnte nicht gefunden werden.~~Fehler! Verweisquelle konnte nicht gefunden werden.~~*** *~~5.3~~*
ST_01	**F**	The system will include inertial sensors	Inertial sensors will collect data about acceleration, angular velocity and/or magnet field out of which it would be possible to extract the information regarding the orientation and relative position of the sensor in the space using specific algorithms
ST_02	**F**	The system will include pressure / force sensors	Pressure and force sensors will mainly collect information about forces and loads
ST_03	**F**	The system will include physiological sensors	Physiological sensors will include heart rate and will collect information about dynamic health indicators such as fatigue or exhaustion.
ST_06	**F**	The system will include environmental sensors	For example: noise, indoor air quality, distance… Barometric pressure, air humidity and temperature

Table 2: User defined requirements

2.2 Medical Requirements

The medical requirements for the BIONIC system and its applications is defined in the deliverable D1.3. In the following Table the medical parameters are mapped to the required sensors.

The sensors provide the measurement input for the BIONIC system to address the target health problem and to predict on the associated risk factors.

According to discussion post D1.3 delivery, the respiration rate was introduced as potential additional medical parameter to be used to identify fatigue and high work load.

Medical parameter	Health problem	Risk factor	Type of data	Mapped to user defined Sensors
Dynamic back/shoulder/neck posture	Joint/ muscle pain, Tension/ stress	Bad body posture, Time pressure, High work pace	Kinematic data	ST_01 – inertial sensor
Duration of static posture	Joint/ muscle pain	Bad body posture	Kinematic data	ST_01 – inertial sensor
Loading/ lifting weight	Joint/ muscle pain	High weight and frequency of lifting	Kinetic data	ST_02 – force sensor
Respiration	Fatigue/ exhaustion, Tension/ stress	Time pressure, High work pace	Physiological data	ST_04 – respiration sensor
Temperature	Tension/ stress	Exposure to heat, noise, poisonous fumes	Temperature, Humidity, barometric pressure, acoustic, gas	ST_06 – environmental
Heart rate	Fatigue/ exhaustion, Tension/ stress	Work-life imbalance, Time pressure, High work pace	Physiological data	ST_03 – heart rate sensor
Daily activity level	Fatigue/ exhaustion, Tension/ stress	Work-life imbalance	Kinematic data from light BSN	ST_01 – inertial sensor
Sleep pattern	Fatigue/ exhaustion, Tension/ stress	Work-life imbalance	Physiological data from light BSN	ST_01 – inertial sensor

Table 3: Sensors defined by medical requirements

2.3 System and functional Requirements

The overall system architecture and technical specification are defined in the D1.5. In the following chapter we will outline requirements which will have an impact on the sensor selection and on its implementation.

Generic Sensor requirements within the BIONIC use case:

- State-of-the-art
- Wearable, unobtrusive, integrated into everyday clothing or work wear
- Integration friendly into textile material
- Low size and weight
- Optimized PPP (performance versus power versus prize)

2.4 Technical Requirements

- High accuracy of sensor data in physical units (internal calibration)
- Low noise – good RMS signal
- Provide data on standardized interfaces I2C, SPI
- Temperature drift compensated data

2.5 Electrical Requirements

Sensors mandatory electrical requirements:

- Operating condition supply Voltage between 1.8V – 3.3V
- Low power consumption << 10mA @3.3V
- Electromagnetic compatibility and immunity

2.6 Mechanical Requirements

- Resistant against mechanical stress
- Small, thin and flat implementation
- No sharp edges
- Water resistant (IP44)

3 SENSOR SELECTION

Part of a user-centered approach is understanding the context in which the end-users will use the BIONIC system, and which (health-related) problems they might experience, and the BIONIC System will address.

The results of this process were outlined in Chapter 2 and lead to a list of possible sensors of the BIONIC BSN. The list of sensors was filtered by an additional questionnaire process, where we have asked the BIONIC user about the use case of the sensor data. Further we have asked for what purpose the sensor data measurement will be used and in which tool the sensor data will be processed.

The background here was to align the sensor selection and sensor data acquisition to the GDPR process, where the purpose definition of the sensor data is mandatory.

In a final step in the sensor selection process, the technical stuff has reviewed the list of sensors and verified whether the usage of the sensor is feasible, quantified the importance of sensor data to achieve the goals of BIONIC, whether the sensor could be integrated into the BIONIC BSN and followed the generic requirements as outlined in Chapter 2. The results of this process will be outlined in Chapter 3.3 as the result of the sensor selection process.

3.1 SENSOR SELECTION BY QUESTIONNAIRE

We have setup a questionnaire applies to the BIONIC User and asked for feedback on the sensor data usage model to obtain the sensor selection. In the additional input to the D1.5 you will find the Questionnaire provided to the BIONIC user „***Bionic Generic Component - Google forms - Analytics.pdf***". The following table provides the list of sensors and components which were considered and the condensed user feedback as a result.

Sensor data	User feedback
IMU data	Mandatory
Magnetometer data	Mandatory
Pressure insoles	Mandatory
Heart Rate	Mandatory
Ambient Temperature	Optional
Humidity	Optional
Barometric pressure	Optional
Ambient Noise Level	Optional
Skin Temperature	Optional
Respiration Rate	Optional
Carried Load	Mandatory
Ambient Light	Optional
Bend Sensor	Optional
GPS based localization (only outdoors)	Optional

Table 4: Sensors defined by questionnaire

3.2 NEW SENSOR TECHNOLOGIES

The technical team has reviewed new sensor and technologies which are considered to provide additional value for the BIONIC application. As the BIONIC System will be applied into pilots by M24, the TLR level of new sensor technology of today needs to be at TLR 5 and above or needs to have a fast path into TLR 5. Few examples of this process are provided and be considered as future research topics.

Ultrasonic ToF Sensor – Time of flight sensors could be used to support the posture calculation and orientation of the IMUs placed on the body. We have reviewed the new ultrasonic CH-101 ToF sensor from TDK Invensense. It utilizes a tiny ultrasonic transducer chip to send out an ultrasonic pulse, and then listen for echoes returning from targets in the sensor's field-of-view. By calculating the distance based on the ToF and speed of sound, the sensor can determine the distance of an object relative to a device and trigger a programmed behavior.

The main limitation of this sensor is the operating range which starts from 40mm to 1200mm with 1.0 mm RMS range noise at 300mm range. However, for the purpose of IMU placement on the body we require precise range measurements starting from 3-5 mm range.

ICM42605 – new 6 axis Motion Tracking device from Invensense / TDK – this device is considered to provide accelerometer and gyroscope data at higher quality as the selected ICM20602, with higher sensitivity, less noise at low power. The device provides a new serial data interface of I3C, whereas the current MCUs not. The risk associated with a new device, where the maturity level is unclear, was main argument, not to use this IMU for the BIONIC BSN pilot system. However, we consider implementing smart sensor node with ICM42605 to verify the device in the BSN application, whilst pilot systems will be equipped with ICM20602.

Barometric pressure analysis on sensor nodes to get information about the relative height position on the body.

Textile bend and stretch sensors to (alternative: enable sensor fusion with IMUs to improve posture calculation) get side-band information on body posture and on IMU position on the body.

3.3 Summary of Sensor Selection

In the table below you will get an overview about the outcome of the sensor selection process.

User defined	Defined by Medical requirements	Questionnaire outcome	In scope of BIONIC	Technical advisory
Inertial sensor	Inertial sensor	IMU	high	agreed
		Magnetometer	high	agreed
		bend/stretch sensor	medium	Research
Pressure / Force sensor	Force Sensor	Pressure insoles / Carried load	high	agreed
Physiological Sensors	Heart Rate	Heart Rate	medium	agreed
		Skin Temperature	low	discarded
	Respiration rate	Respiration Rate	medium	agreed
Ambient Sensors	Ambient Temperature	Ambient Temperature	low	agreed
	Humidity	Humidity	low	agreed
	Barometric pressure	Barometric pressure	low	agreed
	Ambient Noise Level	Ambient Noise Level	low	discarded
	Gas, fumes		low	discarded
		Ambient Light	low	discarded
		GPS localization	low	discarded

Table 5: Overview of sensor selection results

For the discarded sensors we will give a brief explanation of items which leads to the negative decision. Please note that the architecture of the BIONIC BSN allows to integrate any sensor, but we need to focus on the most relevant for the BIONIC use cases.

Skin Temperature sensor:

- The sensor requires direct skin contact, which is difficult to achieve in daily and work wear. The implementation needs to be tightly coupled, which is not unobtrusive
- Medical relevance of skin temperature is not well developed

Ambient Noise level:

- Microphones, even if only noise level will be analyzed, have major concerns by end user data privacy
- Noise level at work environment and its impact on fatigue would be a matter of research which is beyond the scope of BIONIC

Gas and fumes:

- Gas sensors tend to be very large and not integration friendly to be used as a wearable sensor integrated into work wear
- Gas sensors are very selective to a specific gas

- The BIONIC BSN is in principle capable to support gas sensor data and we understand the motivation of industry partner to implement – however that is beyond the scope of BIONIC

GPS localization:

- The purpose of the localization data to the scope of BIONIC is unclear
- Data privacy concern by the end-users
- Localization can be easily enabled with a Smartphone

3.4 Summary of Sensor Implementation

In the following table we provide the information which sensor implementation was selected and provide key items why it was selected. It is beyond the scope of this document to thoroughly outline why a specific sensor is used. One key item to outline here, which applies to all sensors, is that raw sensor data is required to be able to fuse data at system level. That requires sensors with open access to the internal data.

Sensor Category	Type of Sensor	Sensor Implementation	Key items for the selection
Kinematic/kinetic	IMU (MEMS based)	ICM20602	State of the art, mature, high accuracy, low noise, good PPP
	Magnetometer	MMC3416	State of the art, high accuracy, low noise, high data rate
	Force Sensor Pressure insoles / Carried load	Moticon Insole, IAW textile-based pressure sensor	Specific sensor implementation required to focus on feature of carried load Integration into BSN, implementation requires adaption to work shoe
Physiological	Respiration rate	yarn based stretch sensor	Unobtrusive, integration into textile material, access to raw data
	Heart rate	optical - as part of a SmartWatch	Unobtrusive in the smartwatch implementation
Environmental	Temperature, Humidity, Bar. Pressure	BME 280	State-of-the art, mature, low power, high accuracy

Table 6: Summary of sensor implementation

4 Sensor Implementation

In the following chapter, we will outline the characteristics of all selected sensor and its implementation. The given information is not a detailed technical specification. More detailed information will be part of the technical specification and will be provided as reference in the BIONIC technical documentation repository.

4.1 Kinematic/kinetic Sensors

Inertial Measurements Unit ICM20602 (TDK Invensense):

The ICM-20602 is a 6-axis Motion Tracking device that combines a 3-axis gyroscope, 3-axis accelerometer with main features of:

- 3-Axis Gyroscope with Programmable FSR of ±250 dps, ±500 dps, ±1000 dps, and ±2000 dps
- 3-Axis Accelerometer with Programmable FSR of ±2g, ±4g, ±8g, and ±16g

With a high-performance characteristic of:

- Gyroscope sensitivity error: ±1%
- Gyroscope noise: ±4mdps/√Hz
- Accelerometer noise: 100µg/√Hz

The ICM-20602 includes on-chip 16-bit ADCs, programmable digital filters, an embedded temperature sensor, and programmable interrupts. The device features an operating voltage range down to 1.71V. Communication ports include I²C and high-speed SPI at 10MHz.

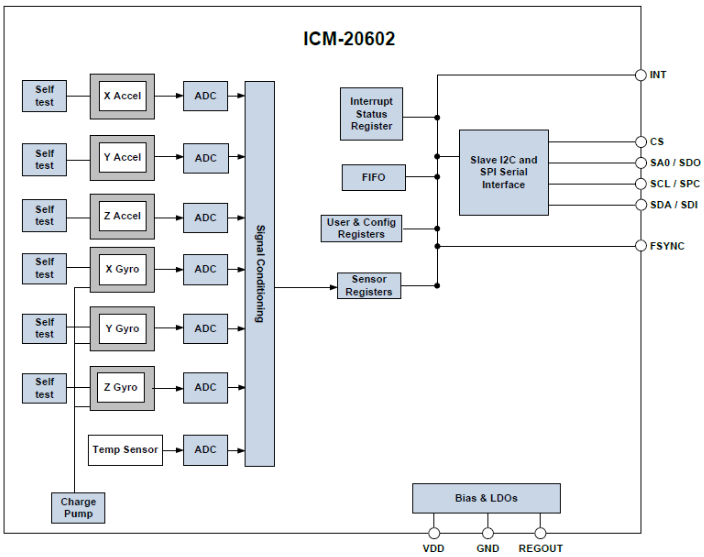

Figure 2: Block Diagram ICM20602

The implementation of the electronic devices, such as outline in Figure 3, will be done on a printed circuit board (PCB) and those will be connected by textile wire into the BSN.

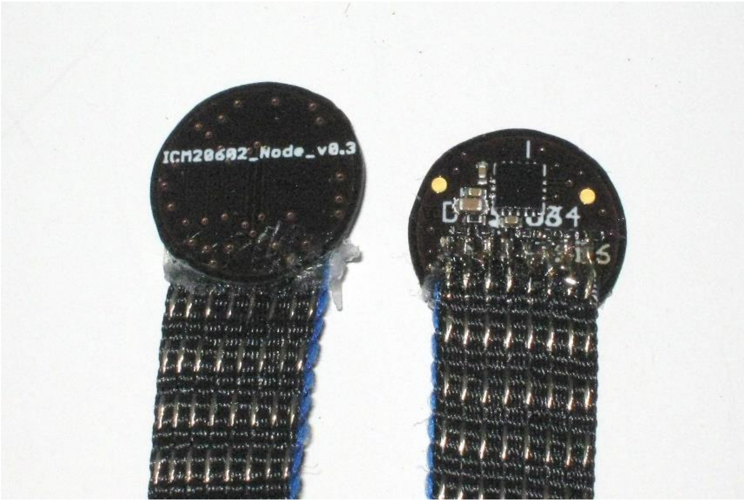

Figure 3: ICM20602 Node Implementation

The methodology how sensors will be integrated into the BSN and the architecture of the BIONIC BSN will be part of the Deliverables D2.5.

Magnetometer MMC3416 (Memsic):

The MMC3416xPJ is a complete 3-axis magnetic sensor with on-chip signal processing and integrated I2C bus. The device can be connected directly to a microprocessor, eliminating the need for A/D converters or timing resources. It can measure magnetic fields within the full-scale range of ±16 Gauss (G), with 0.5 mG/2 mG per LSB resolution for 16/14 bits operation mode and 1.5 mG total RMS noise level, enabling heading accuracy of 1º in electronic compass applications.

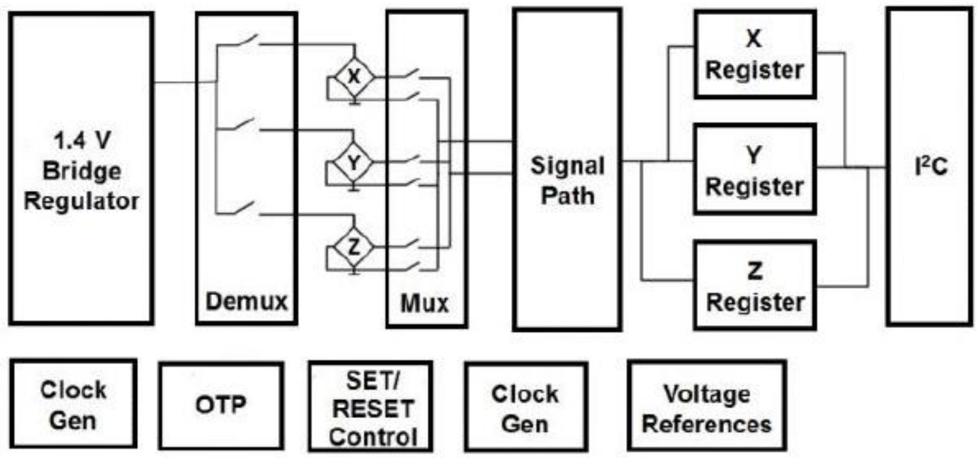

Figure 4: Block Diagram of MMC3416

Pressure insole:

The insole application in BIONIC has a limited scope and is very specific to the use case. There are two implementation options considered. One option is to use a commercially available insole for research application from the company Moticon. A second option is to develop a custom version of a pressure insole with focus on BIONIC requirements.

The purpose of the pressure insole is to identify additional load taken by the worker with following requirements:

- Limited sensitivity, capable to distinguishing load categories 0-10 kg, 10-20 kg, above 20 kg of load, based on OWAS (Ovako Working posture Assessment System) for ergonomic risk assessment
- Integrated into a work wear shoe which is used by the pilot workers (today)
- The insole needs to provide data for a full working day of 8 hours.
- The data needs to be synchronized and fused with the body posture data of the BSN

The Moticon SCIENCE sensor Insole could be used to start the algorithm development. In parallel a custom version of the pressure insole will be developed, which will focus on BIONIC requirements and use cases. A key item of this customization process is the integration into the work wear shoe and a wireless communication to the BSN via NFMI technology.

Despite, the decision to develop a custom version of a pressure insole, we would like to outline the concept of the pressure insole with the Moticon insole.

The Moticon SCIENCE Sensor Insole is a professional measurement tool for sensing foot dynamics. It is tailored for gait and motion analysis in clinical research. The sensor insole is fully integrated, highly flexible and incorporates all technological components to execute standalone measurements. No cables or external devices are required for data acquisition.

Quantity	Type	Axis	Range	Resolution	Hysteresis	Calibration
16 per side	capacitive plantar	Z	0-50 N/cm²	0.25 N/cm²	≤ 1 %	in-production lifetime

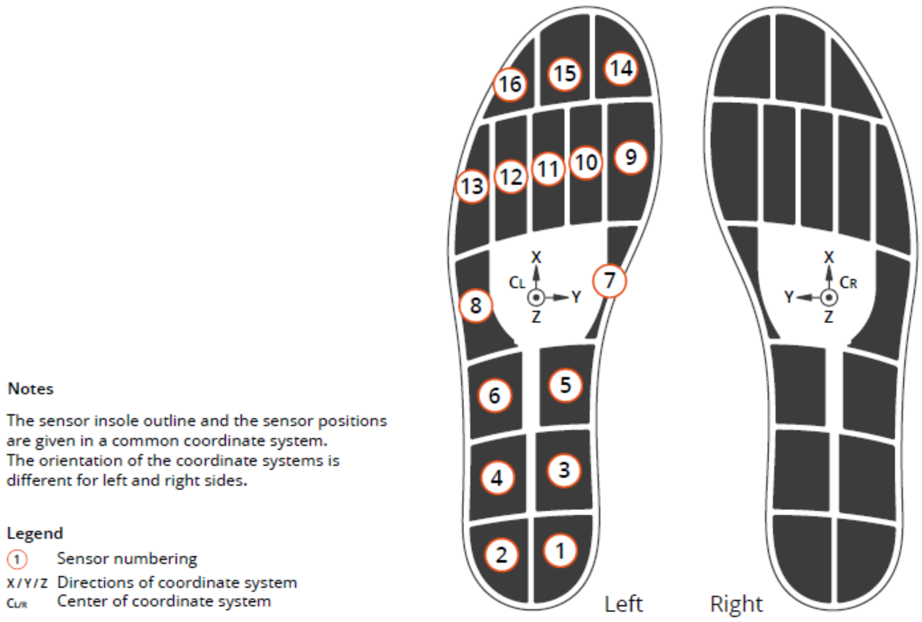

Figure 5: Moticon insole outline

The textile-based pressure sensor is built upon a yarn with a changing resistance as function of pressure. A suitable pressure sensor was developed, by woven the yarn into a textile band and add strains to be used as contact layer.

An implementation specification is given in the table below. Three sensor area implementations will be targeted. For the fore foot the bare foot and the middle area. The middle foot area could also be used as indicator for a fatigue level of the worker.

The sensor yarn and implementation will be developed to meet the BIONIC requirements. The full mechanical system of a work wear shoe, insole, pressure sensor needs to be characterized and optimized to the requirements of the use case.

# of area	Type	Axis	Force Range	Pressure Range	Resolution
3	resistive	z	30-80 N	20N/cm²	10N

Table 7: Pressure insole characteristics

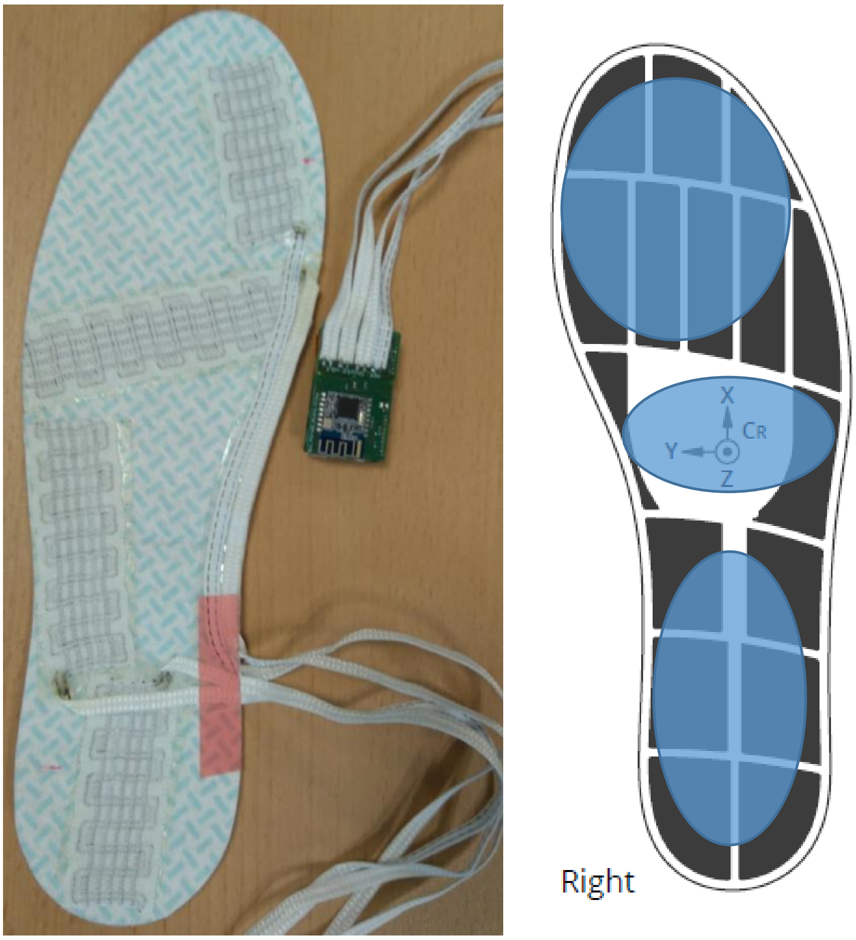

Figure 6: BIONIC pressure insole demonstrator

The calibration of the pressure insole to obtain physical units, the signal processing and algorithms and models to calculate the force is expected to be a challenging task.

Promising results were seen, when additional information of the body mass is considered. The weight up-loads and off-load trigger were identified and a model could be learned on this data set.

Pressure measurements with insole and shoe (and shoe insole) showed that implementation details of the shoe are a significant parameter of the system and need to be considered in the force estimation.

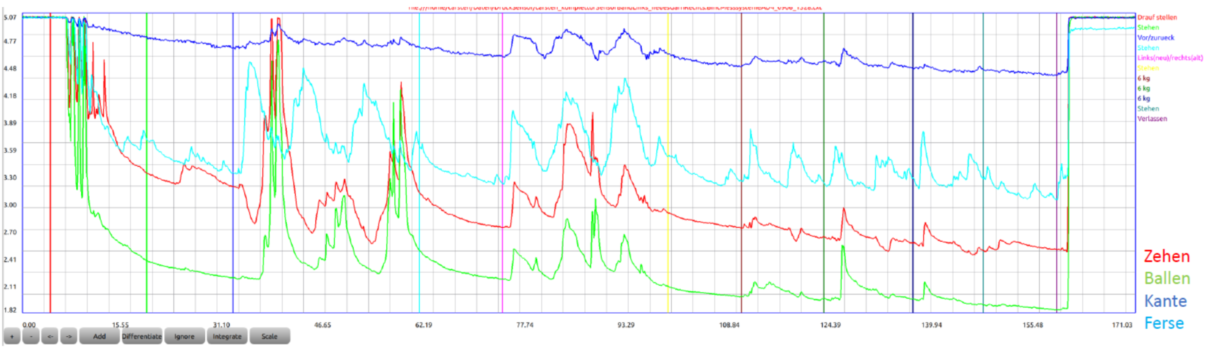

Figure 7: BIONIC pressure insole measurements

4.2 Physiological Sensors

Heart Rate by Polar Smart Watch:

Polar Smart Watch measures heart rate from the wrist with sensor fusion technology. This innovation combines optical heart rate measurement with other sensor technologies in order to rule out involuntary movement that might disturb the heart rate signal and produce unreliable readings.

The data from the Smartwatch will be send via BLE to the BIONIC Application Hub or to the Smartphone. There is no option to customize the data on the watch, but it could be fused with BIONIC data to provide better context and more reliable data.

Further Implementation of a heart rate sensor will be provided by Polar (chest band) which can be used to characterize the quality of the optical heart rate sensor.

Respiration Rate:

The respiratory rate sensor is based on a conductive silicone rubber filament with a changing resistance as function of elongation. With good tensile strength and elongation at break (more than 300 %), this elastic yarn is characterized by its low electrical resistivity (less than 2 Ohm x cm) obtained by adding a high conductivity carbon black to the silicone rubber. This conductive filler forms a continuous network within the rubbery matrix that allows for an efficient electronic conduction even under an intense strain of the filament. In particular, the electric response is linearly proportional to the filament elongation within an ample range of deformation. This linear resistance increase as related to deformation is perfectly reversible and it has been tested over a large number of elongation/relaxation cycles demonstrating a good stability and reliability over time.

The material has been tested also relatively to possible ageing effects. During a two years period of storage at standard condition (room temperature and humidity) no alteration of the electrical or mechanical properties has been noticed demonstrating the effectiveness of the producing process and the reliability of the material.

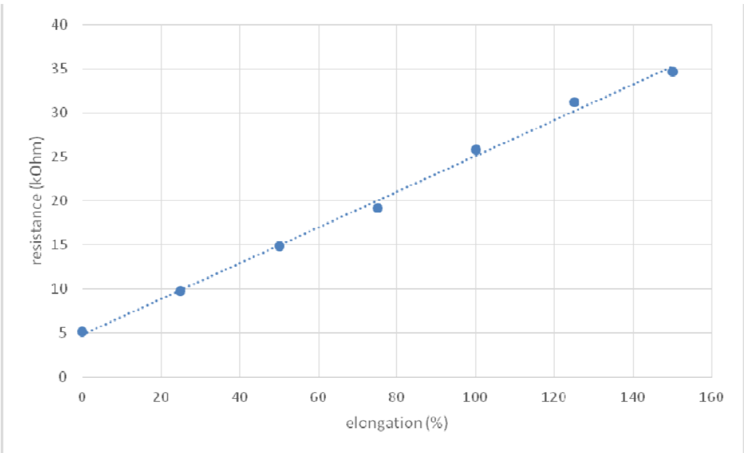

Figure 8: Stretch Sensor resistance versus elongation

All these peculiar characteristics means that the stretch-sensor could be used for many applications as a sensor component to monitor deformations, static or rapidly changing over time, with a fast responsiveness and reliability over a wide range of temperature.

The stretch-sensor requires one channel A/D converter on a Micro Controller which maps the elongation to a digital signal feed into a respiration rate algorithm. The respiration rate is measured by counting the number of breaths for one minute through counting how many times the sensor is stretched. The MCU provides the respiration rate to the Smart Sensor Hub. The adaption of respiration rate algorithm to the final implementation into a shirt is required and planed.

Several implementation options of the respiration sensor have been tested and results were compared. Medical advisories have reviewed the results of the sensor implementation. There are two feasible sensor implementations considered in BIONIC.

- Integration in the chest region – named chest respiration sensor
- Integration in the waist region – named waist respiration sensor

Figure 9: Respiration sensor integrated into shirt

The sensor data fusion of the respiration rate with physical activity, body posture, weight lift and environmental sensors provides a rich information of the workers condition and the context of the data.

4.3 Environmental Sensors

BME280:

The BME280 is an integrated environmental sensor developed specifically for mobile applications where size and low power consumption are key design constraints. The unit combines individual high linearity, high accuracy sensors for pressure, humidity and temperature in an 8-pin metal-lid 2.5 x 2.5 x 0.93 mm³ LGA package, designed for low current consumption (3.6 µA @1Hz), long term stability and high EMC robustness.

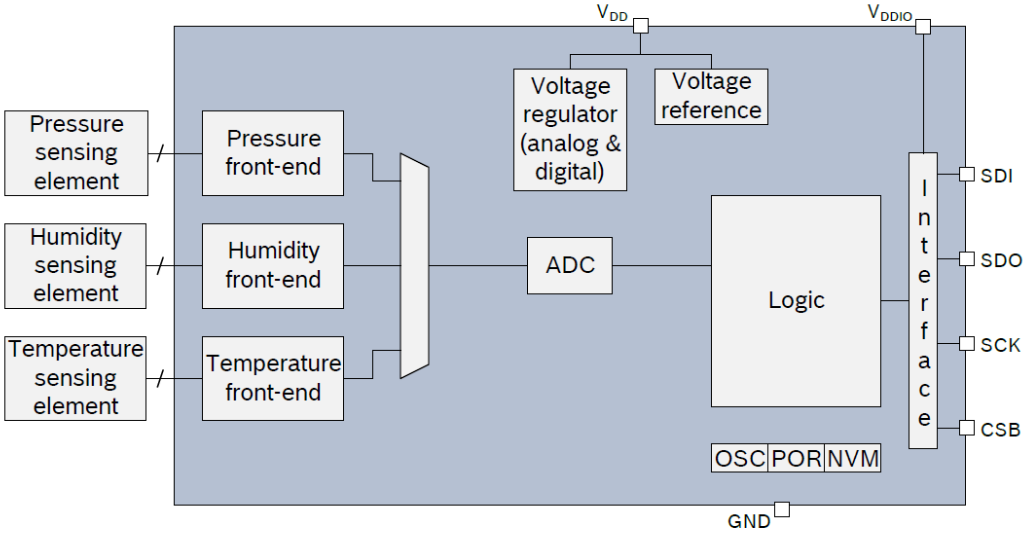

Figure 10: Block Diagramm BME280

NTC-Thermistor (SMD 0402):

The Chip NTC Thermistors is an excellent sensor for temperature measurements in harsh environments. The NTC have a Ni barrier termination and provide high stability in environment by unique inner construction.

The NTC Thermistor requires an A/D channel on the Micro Controller and a calculation of the measured resistance to a given temperature. Those values will be provided by the NTC supplier.

5 CONCLUSIONS

This deliverable has presented the kinematic, physiological and environmental sensors to be used in BIONIC BSN. The sensor selection was focused on the BIONIC use cases and gave the user defined requirements the preference. The sensor implementation follows the requirements to be wearable and capable to be integrated into the daily wear and work wear.

In principle the BIONIC BSN architecture of distributed smart sensor nodes is capable to integrate any sensor, hence the user interests and application will be the main driver in the future to enhance the BIONIC BSN with new sensors.

6 ANNEXES

Additional information, such as detailed technical specification of the sensors, will be given in the Deliverables folder of D2.1 in the subfolder folder "Additional Input"