Wearable Device

Related terms:

IoT, Measurement, Angle Joint, Textiles, Wearable Technology, Measurer

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Human Body Communication–Based Wearable Technology for Vital Signal Sensing

Jingjing Shi, Jianqing Wang, in Wearable Technology in Medicine and Health Care, 2018

11.10 EMC Test Method for a Wearable Device

Wearable devices operated in a body-centric network system require EMC testing to ensure that they can be used for vital signal collection and transmission without failing or causing other devices to fail. So in such a humanized environment, existence of human body cannot be disregarded for EMC test. However, basically in a practical EMC experiment, realistic human body is not permitted, so that the generation of a series of pseudo-signals which can simulate realistic vital signals of human body is necessary, particular in an EMC immunity testing.

Fig. 11.12 shows the composition of our developed pseudo-vital signal generator. The vital signal such as ECG or EMG signal, gathered as a series of digital data with a sampling frequency of 2 kHz and quantization level of 8 bits, is stored as preliminary preparation in a PC for its reproduction. After conversion with optimal amplitude, this digitized vital signal will be sent to the control circuit through serial port, and then the digital-to-analog (DA) converter to reconstruct the analog vital signal with a shaping filter. In this way, it is possible to simultaneously output the reproduced vital signals at a maximum of four channels. As a verification example, the EMG signal reproduced by the pseudo-vital signal generator is shown in Fig. 11.13, to compare with the realistic EMG signal. A perfect match can be seen obviously there, and the correlation coefficient between the reproduced pseudo-vital signal and realistic signal was found to be as high as 0.99. Such a well-reproduced pseudo-EMG signal can provide a good insight into the immunity testing for application of myoelectric-controlled arm prosthesis. In this case, the pseudo-EMG signal can be learned and translated into information by myoelectric prosthetic arm, and then the electric motors can use the translated information to control the artificial arm movements as one expected. Of course, the possibility of using a pseudo-EMG signal in an immunity testing for myoelectric-controlled arm prosthesis has been confirmed experimentally.

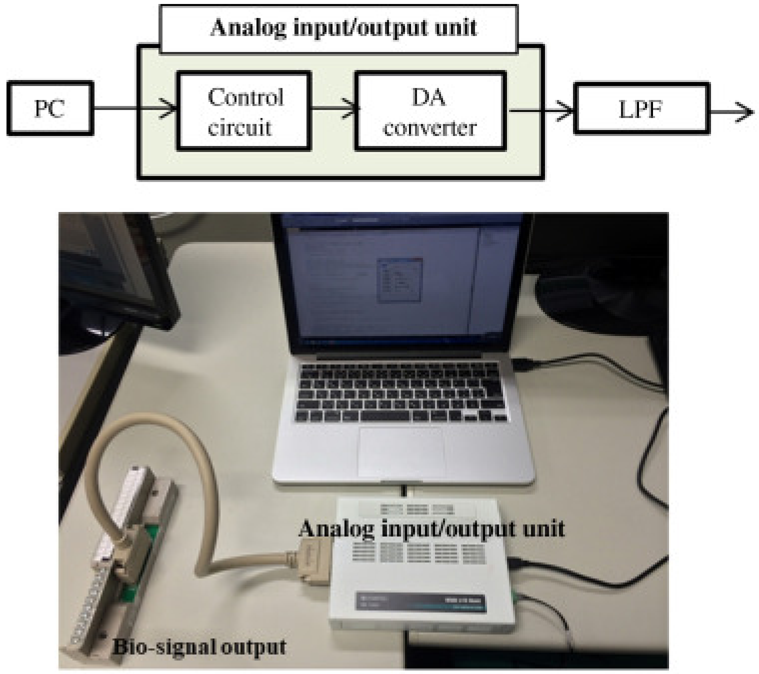

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Figure 11.12. Composition of pseudo-biological signal generator for EMC testing.

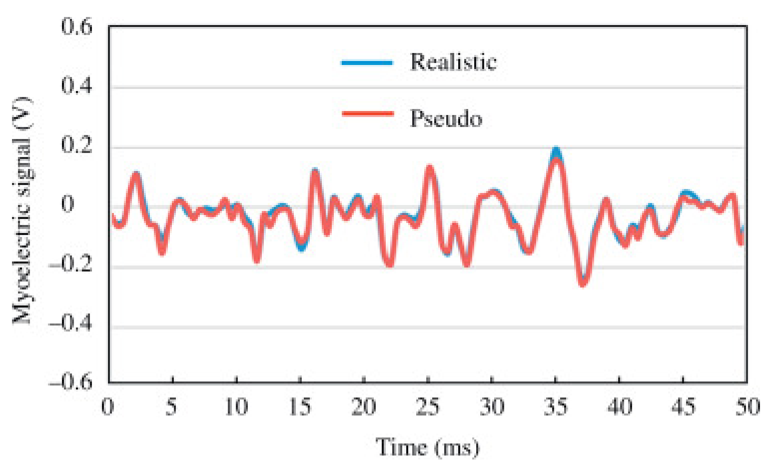

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Figure 11.13. Comparison of the myoelectric signal reproduced by the pseudo-biological signal generator and the realistic one.

For the wearable devices attached on human body, we thus can provide a basic immunity test method as depicted in Fig. 11.14, an illustration of immunity testing system using pseudo-vital signal generator and biological tissue-equivalent phantom. A solid biological tissue-equivalent phantom is used as the substitute of realistic human body. In order to make the biological tissue-equivalent phantom act as human, the pseudo-vital signal generator is embedded into the phantom by means of connecting with two output signal electrodes inside the phantom. In this way, immunity experiments for the wearable devices under test can be conducted to verify whether or not they cause malfunction for the detection and transmission of pseudo-biological signal. Therefore, instead of realistic human body, our suggested testing method by using a biological tissue-equivalent phantom incorporated with a pseudo-vital signal generator can provide a good solution to deal with these kinds of wearable devices for engineers in the corresponding EMC tests. Since the international standards on EMI and EMC test are still under way, this work also contributes to providing suggestions and promoting international standardization process for wearable medical devices.

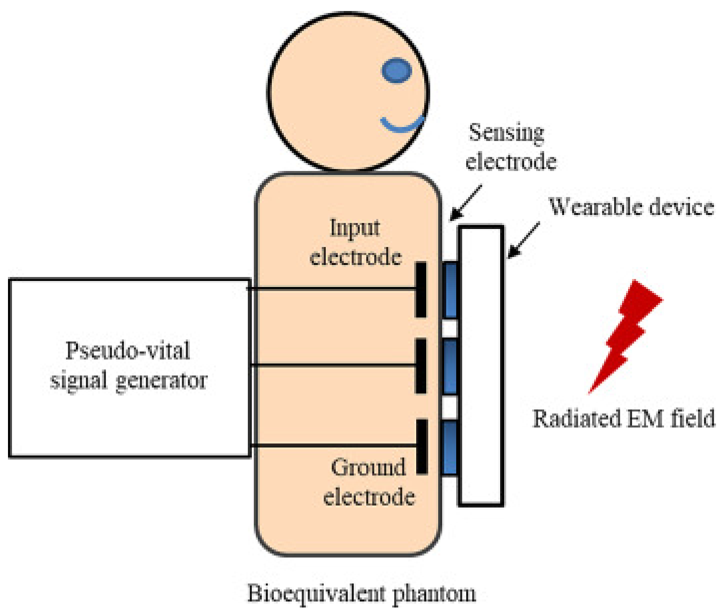

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Figure 11.14. Mechanism of EMC testing for a wearable device based on pseudo-vital signal generator and biological tissue-equivalent phantom.

Introduction

Xiaoming Tao, in Wearable Electronics and Photonics, 2005

Output interface

Wearable devices have output interfaces by which information is presented to the wearer. Vibration (tactile) interfaces have been used. An example of this is the vibration function in mobile phones, by which the user is silently alerted to an incoming call. Many portable devices use audio interfaces. In both cases, the amount of information given is quite small. Voice synthesis (the opposite of voice recognition) via earphones is an alternative, as the wearer does not need to decode the message and can understand it directly. A third category of output interface is the visual interface. These include, for instance, seven-segment or dot matrix displays, liquid crystal displays (LCDs), organic and polymeric light-emitting diodes (OLEDs and PLEDs), and fibre optic displays (FODs). The displays may take two forms: wearable flat panel displays or head-mounted displays.

The main display technology used in portable electronics today is the LCD screen. It is neither flexible nor lightweight. Moreover, it can be bulky and its angle visibility is poor. Holographic polymer dispersed liquid crystals (HPDLCs) are still in their infancy; however, they may offer better performance in terms of flexibility. Polymer light-emitting diodes (PLEDs) are very promising candidates for future wearables, as they have high contrast, a high level of brightness, require much less power and are flexible. Flexible displays based on polymeric fibre optics are also being investigated by a number of researchers.

Electroactive polymer actuators take the form of fibres, yarns and structures based on thin film. They are used as artificial muscles for robotics. According to their actuating mechanisms, they can be broadly divided into two groups: electronic and ionic. The electronic polymers include electrostrictive, electrostatic, piezoelectric and ferroelectric polymers. They can hold induced displacement when a DC (direct current) voltage is applied and have a high level of energy density in air. However, a high activation field greater than 150 V μm^{-1} is required. Ionic polymeric materials include polymer metal composites, conducting polymers and polymer–carbon–nanotube composites. They normally perform actuation in a solution and have a low activation voltage of 1–5 V μm^{-1}. All of these actuators have limitations for use in wearable devices. A promising new technology is based on the dielectric elastomer, which is activated with low voltage in the air and is very robust and flexible. Books by Tao (2001) and Bar-Cohen (2001) provide very comprehensive accounts of dialectric elastomers.

Future of microfluidics in research and in the market

Adam Bohr, ... Henrik Jensen, in Microfluidics for Pharmaceutical Applications, 2019

6.1 Increased Interest in Wearables

Wearable devices are becoming increasingly popular for health care purposes. The growth of industries, such as remote patient monitoring devices and home health care, is expected to influence demand for wearable medical devices over the course of the next years. The explosion in wearable technology has mainly been seen in relation to health care monitoring, but wearable technology is also relevant for diagnostic and therapeutic applications. The wealth of continuous and real-time data collection can help classify patient populations resulting in higher efficacy of treatment and increased safety. Social media is also having an impact on the use of wearables and health care monitoring encouraging its expansion into the everyday life for both the healthy and the ill, helping to understand the needs of the users

[122]. The high demand for wearable medical devices and remote patient monitoring has fueled numerous possibilities, with an estimated 113 million units of wearable devices shipped in 2017 alone, with a market value of approximately USD 20 billion [123,124].

Before describing the development and application of smart wearable systems, it is important to clarify what the term, wearable system, actually covers. In the broad sense, wearable systems are systems that have one of the following features: wearable, portable, implantable, and ingestible. They can comprise a patch, sensor, actuator, fabric, textile, fiber, clothing power supplies, wireless communication, multimedia devices, software, etc. They can be worn as an accessory or embedded as part of clothing, carried around and used as needed, implanted in the body or ingested as a pill [125]. They can be used at home, outdoors, work, or clinical setting and can be connected with mobile or stationary equipment.

So far, smartwatches and wristbands have been the focal points of mass-market consumer product development within wearables, which has led to an abundant availability of such devices in the past couple of years. The main players here are companies including Google, Samsung, Nike, Apple, and Fitbit. Although these devices are mainly focused on fitness applications and other activities, there is an increasing demand for wireless monitoring devices, and an increasing incidence of lifestyle-related diseases requiring routine vital statistics and analysis is driving the interest toward health care-related application of wearables. Research within smart wearable systems has concentrated on smart devices and intelligent environments, which displace the interface for computational surroundings to our body, clothes, and portable accessories. Wearables for health care purposes are likely to follow the same trends where small miniaturized devices with a bare minimum functionality can be used together with computation in the environment, for instance, a smartphone [124]. Here, adaptability can be regarded as essential feature of wearable systems for health care purposes, and these should be compatible with smartphones and other devices. Intercompatibility among wearables and standardization of the obtained health care data will most likely also be important features for bundling and correlating all the data acquired in a more holistic health care monitoring approach (Fig. 15.7).

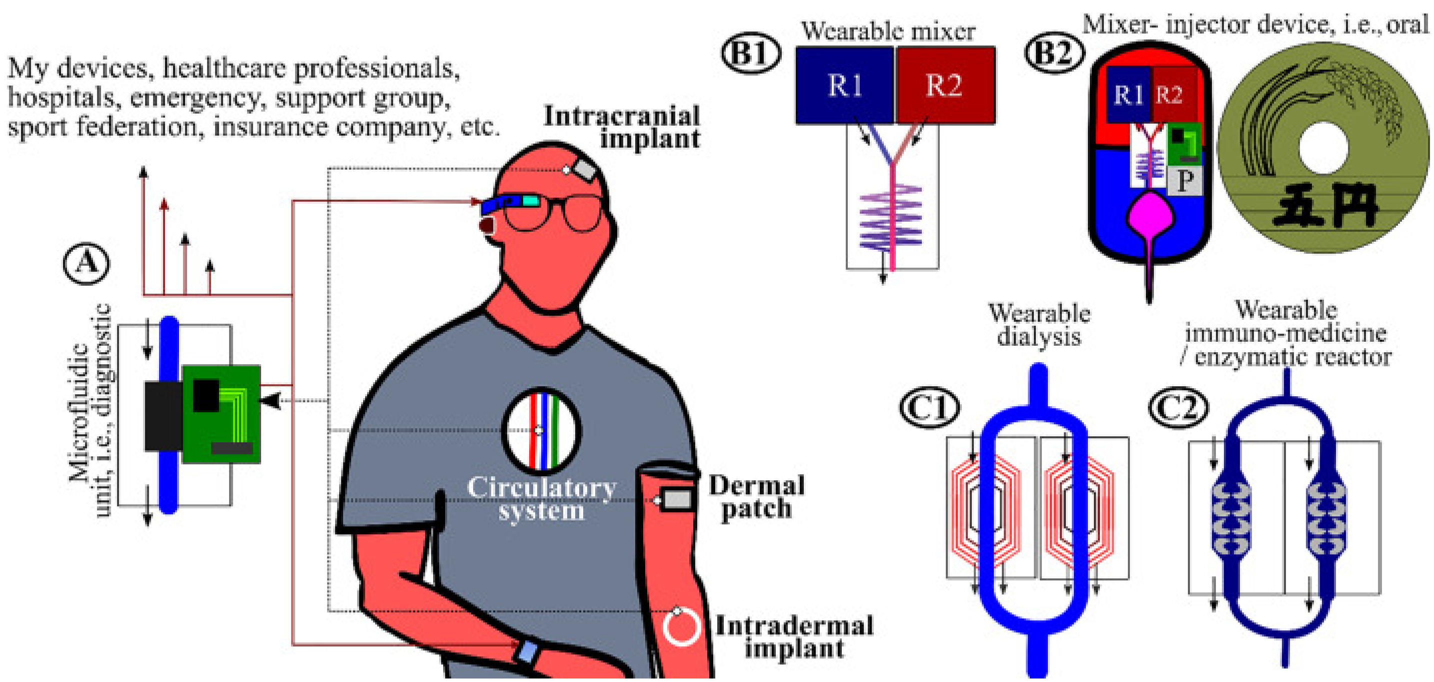

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Fig. 15.7. Wearable microfluidic devices. Miniaturized microfluidic systems can be integrated in (A) dermal, intradermal, circulatory, and intracranial devices for diagnostic, medical, and drug delivery purposes. Monitoring and device control can be exerted through user-controlled accessories (smartphone, smartwatch, etc.) or remotely by health and law enforcement organizations. Examples of medical microfluidic devices are (B1) wearable mixers for self-administration of drugs at flexible dosages/composition; these can also be integrated in micronized delivery devices, that is, (B2) oral devices for intestinal injection of instantaneously mixed stabilized proteins with excipients. Microfluidic surface properties can be also exploited in (C1) wearable dialysis devices or electrolyte exchange devices. Microfluidic channels with (C2) surface-associated antibody and enzyme-based microfluidic systems could provide a wearable system to reduce the spreading of circulating cancer cells or deplete tumor growth.

Internet of things, smart sensors, and pervasive systems: Enabling connected and pervasive healthcare

Pijush Kanti Dutta Pramanik, ... Tanmoy Pal, in Healthcare Data Analytics and Management, 2019

6.3 Different Fitness Devices

Wearable devices, empowered by smart sensors, have elevated modern healthcare support through continuous monitoring of physiological parameters. Devices like pedometers, activity trackers, etc., with the help of various fitness apps, are controlling the way we exercise and maintain a healthy lifestyle with suitable and timely instructions and motivation. For example, sportswear with a smart sensor allows us to improve our performance by forging body data into training advice. Below, a few examples of such fitness devices are discussed.

6.3.1 Wrist band

The advancement of health monitoring sensors has brought commercially usable wristbands. This wristband, also known as an activity tracker or fitness tracker/band [61], assesses a person's physical activity and tracks the health and other vital statistics. The fitness tracker monitors 24/7 heart rate, steps, sleep, stress, VO_2 max, calories consumed, etc. These devices, along with monitoring, also enable wellbeing and staying healthy by advising for exercise, dieting, and sports coaching [62]. The fitness tracker monitors one's health and activity effortlessly using noninvasive sensors in an efficient and very accurate way. The fitness tracker can be synchronized with a smart mobile device, reflecting the person's health status. Mobile intelligence applied over one's past data could provide timely and appropriate health advice.

6.3.2 Eye gear

The health and wellness care industry have come up with eye gear that helps the user with health updates while performing swimming, cycling, and other very fast body activities that demand constant health monitoring. The eye gear constantly monitors one's activity pace, heart rate, cadence and power, etc. The person's health statuses are projected on the glasses and aural prompts are made through the earpiece; this avoids having to look constantly for health and activity status as with other fitness devices such as smart mobile devices and wristbands [63].

6.3.3 Smart shoe

Smart shoes are a new kind of shoes that help in keeping track of physical fitness. These smart shoes can be slipped into very much like a normal shoe, without the bother of wearing extra accessories like a fitness band, making the health and physical tracking quite invisible. The fitness tracker is put into the sole of the shoe to assess the running metrics of an individual. The stored data can later be synced to the mobile device for analysis. These shoes are very useful for preevent training [64].

6.3.4 RFID tags

The simplicity of Radio Frequency Identification (RFID) in terms of operability, wireless sensing, and lower cost has made these tags a popular technique for tagging any object, thereby connecting it to a virtual system. RFID tags principally work on radio wave based identification and tracking technology. The system consists of tags that are identifying devices, readers, or a base station and underlying information system. Commercially different frequency ranges of radio waves have been found in use by RFID tags for communication with reading devices. The tag transmits its ID using an RF signal, which is read by a reader or multiple base stations while in close proximity. On the basis of the usage of an external power source like battery power, the RF tags can be categorized as active or passive [65]. An active tag uses external battery power to transmit a signal and hence it has more transmission power and coverage range. A passive tag uses the received signal's power to boost up and send a modulated signal back, thus having limited transmission range. The distinctive properties of RF signals that make them ideal for identification tracking are:

- Traverses through walls
- Does not require direct transmission path or line of sight
- Operating range up to 30 m or more
- High speed
- Uses low-power transmission
- Supports data rate up to 1–2 MBPS

RFID has contributed to IoT in reaching practical heights. The application of RFID in the medical and healthcare sector ranges from information management to patient monitoring. Though RFID actually does not return direct patient health data, it successfully allows connecting things (living or nonliving) over the Internet and thereby orchestrates various action, operation, and management in an efficient manner.

In medical and healthcare services, some examples of RFID as an enablement of IoT are [66]:

- **Patient information management:** Patient health records containing medical history, ailments, type of treatment undergone and side effects, medication, or medical examinations stored in the database can be linked to RFID. Doctors and nurses administrating the patient can get the details from the patient's RFID tag, which would help in proper diagnosis and preventing wrong medication from being delivered.
- **Information sharing:** RFID system helps to create a strong network for sharing medical information or records. Patients' medical information, stored in the database, is linked to RFID tags. This ensures doctors can skim through the patient's medical records, medical history, treatment procedures and information, insurance coverage, etc. The application of RFID helps the patient to suitably choose doctors and hospitals. The information stored in the database can be well shared among doctors, regardless of space and time. This also ensures the doctors and hospitals are constantly updated with new progress.
-

Constant real-time monitoring: In medical research and production, RFID tags are being used to monitor the entire research, production, and distribution of medical products like medicine and others. While circulating, the users are informed of all the details of medication, thus maintaining quality. If the quality of medication is suspect, all information like name, category, origin, batch processing, delivery, and sales can be traced back.

- **Medication storage management:** RFID tagging system helps to maintain the medical stock, thus reducing manual input error. The RFID systems to maintain stock further help in avoiding name confusion in cases where the medicines have similar names, and also help with stock level maintenance, timely supply of medicine, and reordering.
- **Medical equipment traceability:** Medical equipment linked with RFID tags helps to know what the device is, its origin, period of use, quality issues, what patients have used the equipment, places where the equipment has been used, and used/unused status.

Challenges and Limitations of Data Capture versus Data Entry

Norbert Noury, ... Henri Noat, in Connected Healthcare for the Citizen, 2018

5.2.2 Sensors and behaviors

Although wearable devices have the potential to facilitate changes in health-related behaviors, these devices alone do not necessarily lead to changes. In fact, the successful use and potential health benefits linked to these devices depends more on the design of patient engagement strategies than on technological specifications. These engagement strategies are combinations of individual encouragement, social competition and collaboration, and effective feedback loops which can modify human behavior.

This topic joins the debate on open observance in Chapter 2:

“Concerning chronic diseases, observance is expected throughout. The statistics clearly show that this is a public health issue. But what is the cause? How and under what conditions would being connected improve this observance?”

Methods to develop mathematical models: traditional statistical analysis

Jorge Garza-Ulloa, in Applied Biomechatronics using Mathematical Models, 2018

5.1.4.3 Example of probability distributions

Case for research: Probability distributions for the measurement of angles in Goniometers sensors

Background for this research

A wearable device to measure angles (Goniometers) is used in this example to obtain the sagittal relative joint angles for the knee from the right limb. The original data file was processed to obtain the matrix cycle gait (MGC) for knee right joint angles (note: MGC calculation was explained in Example 4.1.1); this matrix contains in each column all the angles measured in each stride as indicated in Table 5.8, and the name and directory of this processed data file can be found in: "...\BOOK\MATLAB_CH5_JOINT_ROM_PROBABILITY\rKneeY.csv." Note: The rate sample was 100 Hz.

Table 5.8. The Processed Data file for Sagittal Relative Joint Angles for the Knee That Contains the Matrix MGC for 139 Strides With 122 Sample Angles

Stride1	**Stride 2**	**Stride 3**	**...**	**Stride138**	**Stride139**
3.1343	1.509	4.4687	...	1.4961	−0.6811
3.5281	1.5092	3.6642	...	1.6335	0.0016
...				...	...
...				...	...
0	0	2.9504	...	0	0
0	0	2.1438	...	0	0

This data file can be found in: "...\BOOK\MATLAB_CH5_JOINT_ROM_PROBABILITY\rKneeY.csv."

Objectives for this research

Analyze this data file provided with sagittal relative joint angles for the knee from the right limb, using different continuous probability distributions: Normal, Weibull, and *Lognormal*. Follow the below steps to find the best fit probability distribution:

- Chart of the joint angles to observe the variability of the data.
- Calculate the range of motion (ROM) for each stride, and check if the ROM can be used as a random variable for the next probabilities distributions: Normal, Weibull, and Lognormal.
- Chart at least two of the best fit probability distributions.
- Test the probability of the two best probability distributions indicating the difference on the results:
  - Prob ($Z = 64$)=?
  - Prob ($x = 66$)=?
  - Prob ($64 < Z < 66$)=?
- Make conclusions about the different probability distributions used to analyze data.

Response variables to calculate in this research:

The range of motion (ROM) calculated values for each stride

Data analysis for this research

The algorithm to obtain the solution for this research case is shown in Fig. 5.6.

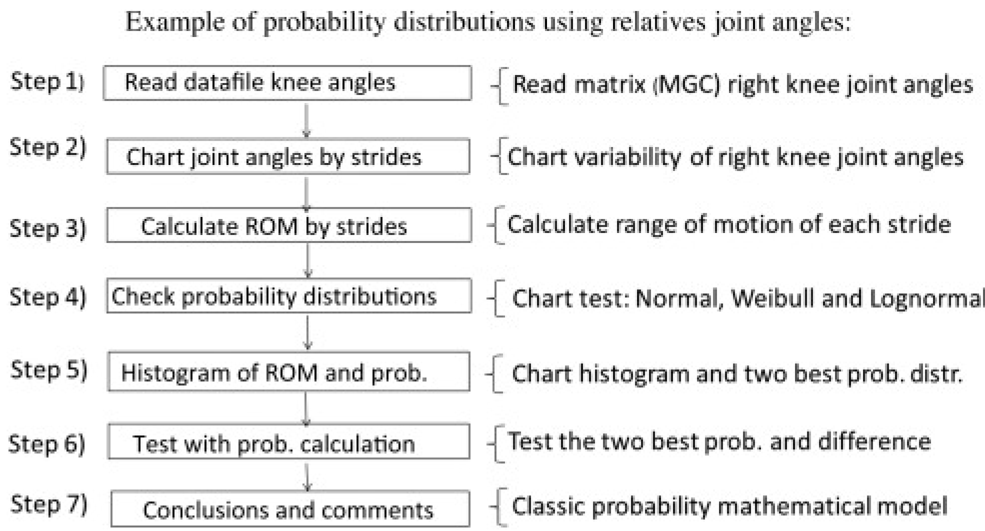

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Figure 5.6. Algorithm to Analyze a Data file of ROM From Right Sagittal Knee Joint Angles, Using Different Probability Distributions.

The MATLAB® code for the algorithm indicate in Fig. 5.6 is shown in Table 5.9.

Table 5.9. The Program Code for the Probability Distributions for the Measurement of Angles in Goniometers Example 5.1.4.3 Is Based on Algorithm of Fig. 5.6

The MATLAB® program can be found in: "…\BOOK\MATLAB_CH5_JOINT_ROM_PROBABILITY\Prob_ROM_rigth_knee.m."

Results, conclusions and recommendations for this research

The program of Table 5.9 following the algorithm is shown in Fig. 5.6, where:

- Step 1) *Read data* file knee angles: In this step the data file that contains a matrix of gait cycles (MGC) of sagittal relative joint angles for the knee from the right limb is read. This matrix contains 122 rows with the samples angles for each stride, and 139 columns where each one is a stride.

- *Step 2) Chart joint angles by strides*: The chart is shown in Fig. 5.7A it represents the variability for the 139 strides of sagittal relative joint angles for the knee of the right limb.

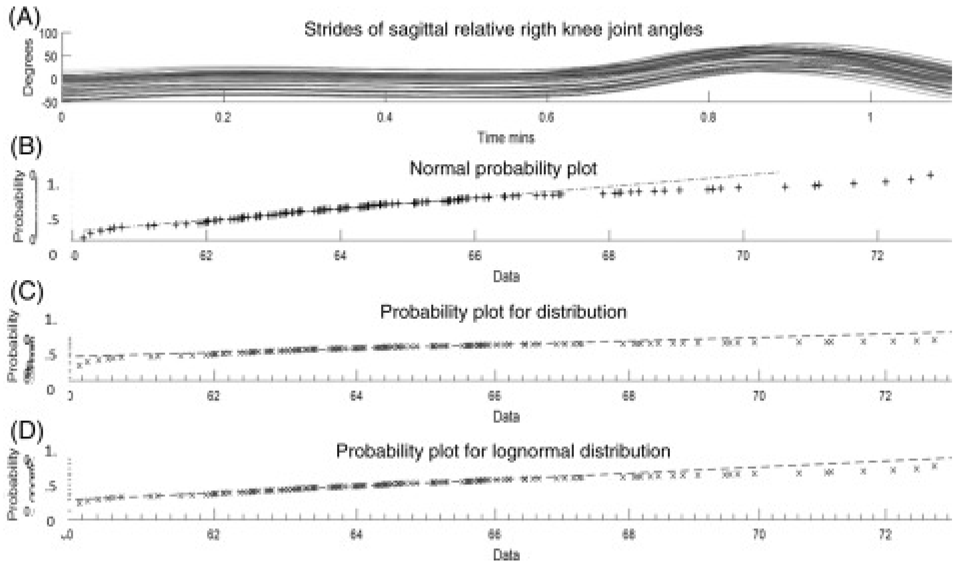

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Figure 5.7. Charts for Probability Distributions in the Measurement of Angles in Goniometers Example 5.1.4.3, Where:

(A) Represent the variability, (B) test probability normal distribution, (C) test probability Weibull distribution, and (D) test probability lognormal distribution.

- *Step 3) Calculate ROM by strides*: In this step, the ROM for each stride is calculated, using the following instructions:

  A=stride_angles;A(~A)=inf;undefinedROM=(max(stride_angles)–min(A));

  These instructions allow calculating the differences avoiding using zero values as the lower angle.

- *Step 4) Check probability distributions*: Here the following instructions are used to test probabilities distributions:
  - Normal probability plot indicated in Fig. 5.7B using instruction: *normplot (ROM)*.
  - Weibull probability plot indicated in Fig. 5.7C using instruction: *probplot ("Weibull",ROM)*.
  - Lognormal probability plot indicated in Fig. 5.7D using instruction: p*robplot ("Lognormal",ROM)*.

    Note: In each probability plot of Fig. 5.7, the "line with the symbols +" represents the real probability and the noncontinuous line represents the ideal probability. If the "line with the symbols +" are closed to the noncontinuous means better fit the probability. The two-best fitted probabilities for the ROM are: Normal and Lognormal probabilities.

- Step 5) Histogram of ROM and Probabilities: this step was subdivided into three substeps:
  - Substep 5a) Generate a histogram as shown in Fig. 5.8A where the histogram is a graphical representation of the distribution of numerical data using range of accumulated data.

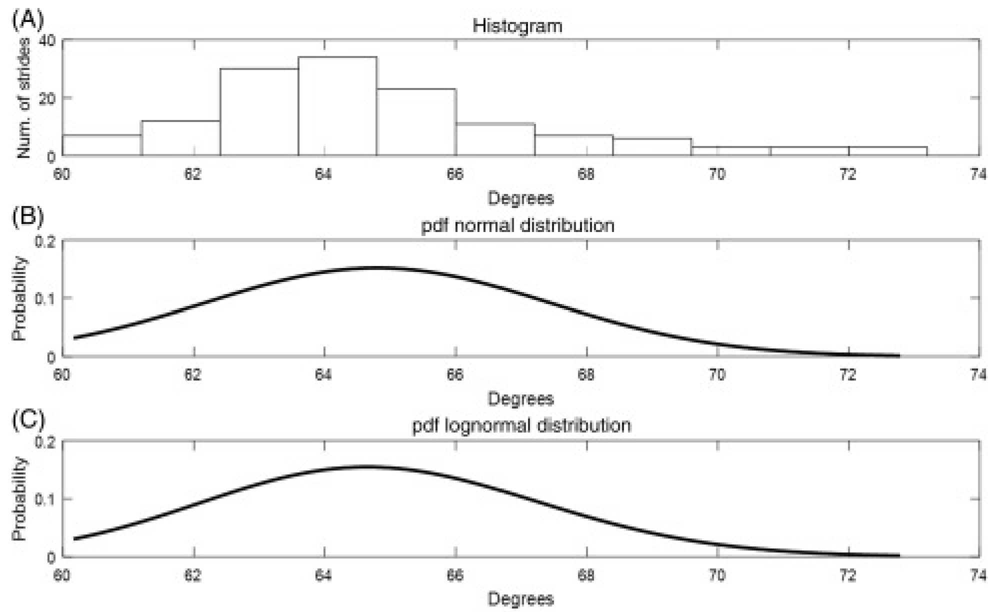

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Figure 5.8. Charts for the Probability Distributions in the Measurement of Angles in Goniometers Example 5.1.4.3, Where:

(A) Histogram as a graphical representation of the distribution of numerical data, (B) probability density function (pdf) of the normal distribution, and (C) probability density function (pdf) of the lognormal distribution.

  - *Subtep 5b) Plot standard Normal distribution* shown in Fig. 5.8B where the chart indicates the pdf (pdf) of the normal distribution.
  - *Substep 5c) Plot standard Lognormal distribution* shown in Fig. 5.8C where the chart indicates the pdf of the lognormal distribution.
- *Step 6) Test with probability Calculation.* In this step, the probabilities requested are calculated to find the differences in values between the normal and lognormal probabilities. The text results are indicated in Table 5.10.

Table 5.10. The Results of Calculation of Probability Distributions for the Measurement of Angles in Goniometers Example 5.1.4.3

- *Step 7) Conclusions*: The lognormal distribution is best fit for this data file, but the results of Table 5.9 indicate that there are small differences in probabilities between normal and lognormal distributions of ∓0.48402%~0.5% of error. This is an indication that the normal distribution can be used too.

Wearable technologies for personal protective equipment

J. Decaens, O. Vermeersch, in Smart Textiles and their Applications, 2016

23.1.2 Various levels of integration

The addition of wearable devices should not impede the comfort of the PPE or the mobility of the wearer. Therefore, a high level of integration is expected but is not always met. Indeed, the level of intimacy between the electronic components and the textile substrate can be classified in three categories:

1. A low level of integration implies that the wearable device is added during the last step of manufacturing – the assembly.
2. A medium level of integration indicates that the functional components are directly embedded within the fabric.
3. A high level of integration entails the incorporation of the active elements within the fibres themselves.

Increasing the level of interweaving between the components of the wearable device and the PPE can be achieved by acting backward on the manufacturing process steps. However, the level of difficulty also increases and can raise further challenges, such as durability after washing cycles, since the functional elements are no longer removable.

Detection and Characterization of Food Intake by Wearable Sensors

Juan M. Fontana, Edward Sazonov, in Wearable Sensors, 2014

5.2 Wearable Devices for Free-Living Monitoring

A novel wearable device, the Automatic Ingestion Monitor (AIM), has been developed and evaluated for objective monitoring of food intake under free-living conditions (Figure 8) [24]. AIM presented three major benefits over self-reported intake. First, AIM is a wearable device that has the ability to monitor 24 hours of ingestive behavior without relying on self-report or any other actions from subjects. AIM wirelessly integrated three different sensor modalities for an accurate monitoring: a jaw motion sensor to monitor chewing, a proximity sensor to monitor hand-to-mouth gestures, and an accelerometer to monitor body motion. Second, AIM is able to reliably detect food-intake episodes in the presence of real-life artifacts using a robust pattern-recognition methodology for detection of food intake. The detection methodology contains several steps, such as sensor information fusion, feature extraction, and classification. The sensor fusion step removes portions of the signal that cannot be food intake based on statistically derived rules. For example, it is highly uncommon to eat solid foods during moderate to vigorous exercise, or during sleep. Both of these activities (exercise and sleeping) can be reliably detected from the accelerometer signal and corresponding signal intervals not included into further consideration for food-intake detection. The feature extraction step computes a number of time, frequency, and time-frequency domain features from the sensor signals. Food-intake detection is based on an artificial neural network implementing a subject-independent classification model that requires no individual calibration. Third, the AIM device and food-intake detection methodology were validated in an objective study where an average food-intake recognition rate of 89.8% was achieved. Individuals with origins from five different countries and having different lifestyles and ingestive behaviors participated in the validation study. They wore AIM in free living during 24 hours without any restrictions on their eating behavior and activities.

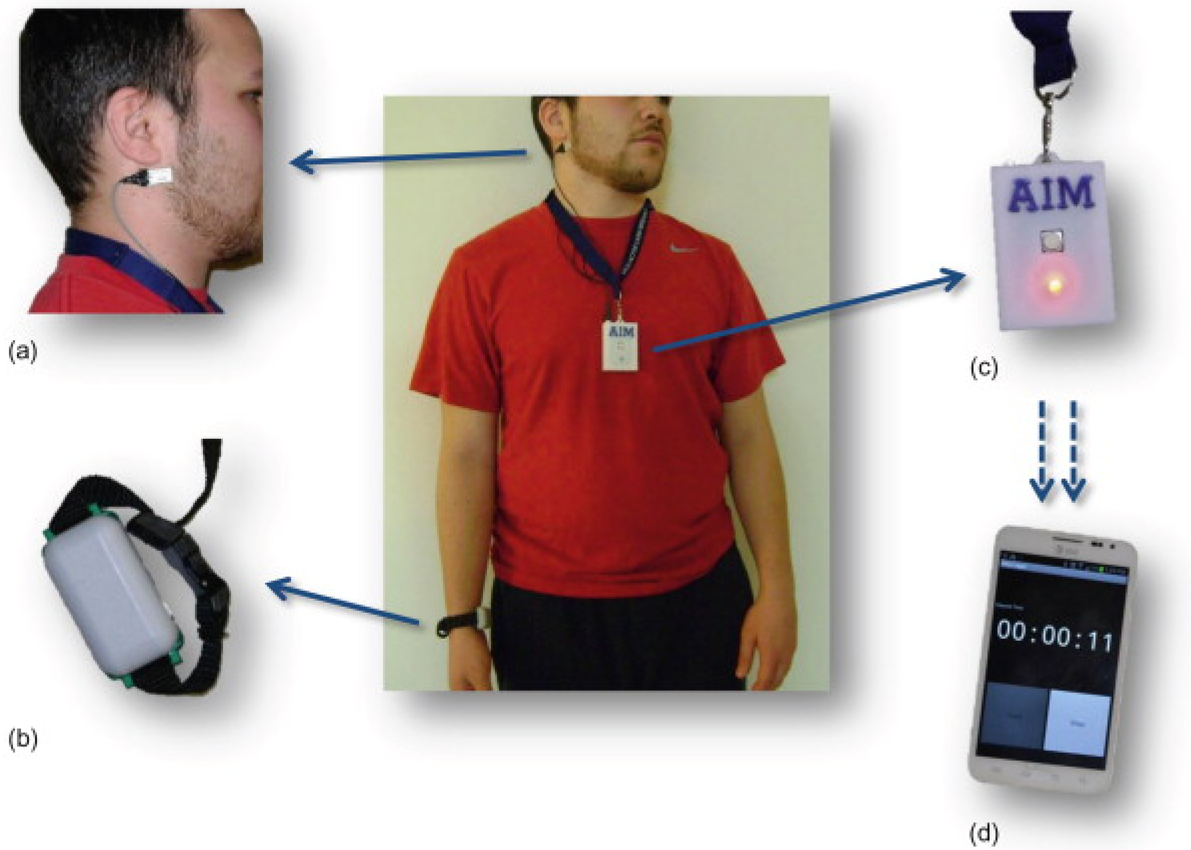

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Figure 8. The Automatic Ingestion Monitor (AIM) consisting of four main parts: (a) the jaw motion sensor, (b) the wireless module, (c) the proximity sensor, and (d) the smartphone.

The results of the validation study revealed that AIM can potentially provide an accurate prediction of the food-intake episodes occurring over the course of a day in a free-living population. However, several questions remain to be answered. One question is related to the capability of AIM for detecting liquid intake. In the validation study, the results showed the recognition rate for solid food intake only. Previous studies suggest that certain intake of liquids (such as gulping large quantities of a drink) may be detected through the monitoring of jaw motion [33] while others, such as sipping, may be undetected. Another question is related to the acceptance of the device by subjects. AIM was designed as a pendant device worn on a lanyard around the neck, which intended to satisfy the need for a socially acceptable device; further miniaturization of the device is needed to make it less obtrusive. Finally, although the food-intake detection was performed offline, the ultimate goal of AIM is to perform real-time recognition and characterization of food intake and to deliver feedback about an individual's intake behavior.

Social Aspects of Wearability and Interaction

Lucy Dunne, ... Clint Zeagler, in Wearable Sensors, 2014

2 Social Interpretation of Aesthetics

Clothing and wearable devices are primarily perceived through visual and somatosensory (sensations of the body) processes. Somatosensory perception is more pertinent to the wearer's own experience of wearability, and more particularly to the experience of physical wearability and body comfort. The communication functions of dress – the ways in which dress helps to define the individual and group identity of the wearer and the wearer's context – are therefore achieved mostly through visual communication. The degree to which perceptions of one's visual appearance are comfortable for the wearer can be interpreted as the social wearability of clothing and worn artifacts.

2.1 Visual Processing of Aesthetics

DeLong [4] describes the clothed or adorned body as the "apparel-body-construct," the combined influence of the visual properties of the body and the visual properties of worn artifacts. The body alone and a garment alone may have discrete properties, but both are modified as they are brought together. The body and the garment each have visual properties which encode meaning – sometimes literally, in the sense of a graphic t-shirt with a text-based message, and sometimes in a more abstract manner, in the sense of the social judgments that accompany wearing a fashion trend, or having a certain body shape. The intersection of the properties of the garment and the body also contributes to the viewer's perception of meaning in "decoding" the identity and context of the individual. For example, a too-tight waistband may constrict the wearer's waistline, producing folds above and below the waist, and distorting the original shape of the garment. This visual cue may be read in any number of ways, depending on other contributing visual factors, and attributed to elements of identity (too lazy to buy new clothes, too vain to admit a size change) or of context (temporarily wearing ill-fitting clothes, following a fashion for cinched waistlines), or both.

A wearable device worn under clothing may produce a bump or distortion to the body shape. This distortion may or may not be obviously attributable to something being worn under the clothes. Figure 1 shows three body-worn volumes (a rectangular shape with square corners, a curved shape, and a bracelet) worn under and on top of clothing. While curved shapes may be perceived as more "ergonomic" or comfortable, when worn under clothing they may be more easily read as a protrusion of the body's surface rather than a concealed technology.


A
B
C
D
E
F

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Figure 1. Three styles of wearable volume in three body locations, worn under and on top of clothing.

DeLong identifies two types of characteristics of the apparel-body-construct: expressive characteristics and referential characteristics (see the left side of Figure 2). Expressive characteristics are direct characteristics of the form itself (visual elements of shape, color, texture, etc.). Referential characteristics are interpreted by the viewer; they are characteristics of the form the viewer understands as related to something outside of the form (such as a brand logo, a visual reference to another time period or a symbol of an occupational role like a badge or white coat). In some ways expressive characteristics are less open to interpretation by the viewer. They tend to play on innate responses and associations (such as bolder colors being perceived as more aggressive, flowing shapes being perceived as softer and more gentle), whereas referential characteristics depend more on the experiences and prior knowledge of the viewer. For example, it is common for teen fashion trends to reference various decades of the past (e.g., 1970s fashion references in the late 1990s and early 2000s; 1980s references in the 2010s). However, while these references may evoke direct memories in older viewers, many of the adopters of these trends have no memory of the time periods they are referencing (and may not even be aware that there is a reference), and may therefore find a different kind of meaning in the aesthetic. The same holds true for wearable systems: while the aesthetic effect of the system may hold one meaning for the designer of the technology, to an observer this meaning may be completely lost, or interpreted as something else entirely. Starner et al. [5] found that the expressive characteristics of a wearable computer were often (at the time) interpreted as being those of a medical device, the nearest mental model that most viewers could compare the wearable to. They found that altering the color of the head-mounted display quickly translated the device into a new referential association: white or light-colored devices were more often interpreted as medical devices, but grey or black devices were more often interpreted as consumer products. This division in device color specifically has blurred to some extent since 1996, but other expressive characteristics of devices still display trends that afford referential grouping by viewers.

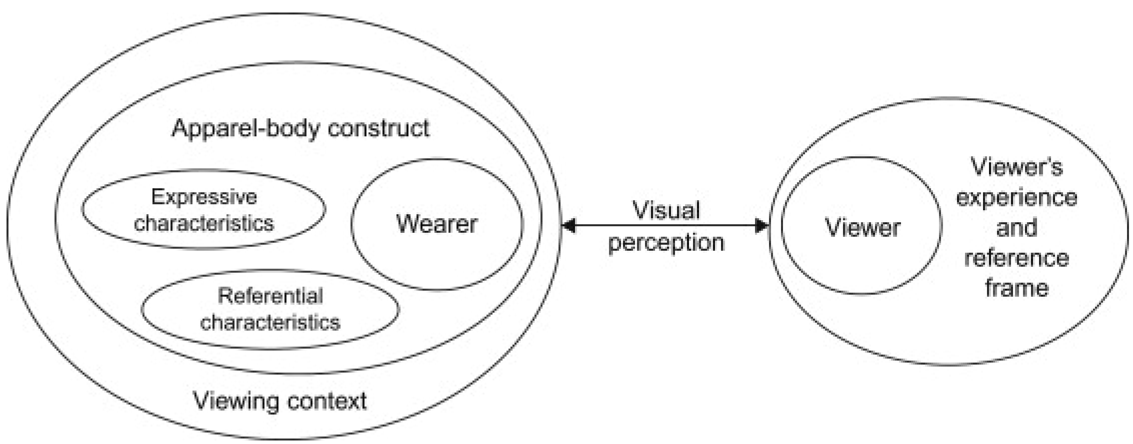

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Figure 2. Visual perception of aesthetics.

Meanings are often defined and agreed upon by groups and sub-groups within a society (Figure 2, right side). Bell described one facet of this definition process as "sartorial morality" – the codes and mores established by a society that govern "appropriateness" of dress. These codes change with context, such that a form of dress that may be appropriate on the beach is rejected in an office setting, or clothing that is appropriate for a younger person may be inappropriate for an older person [6]. While some codes may be explicitly enforced, more often they simply carry undesired social weight: social repercussions in the form of unwanted attention or negative responses that an individual may receive when "inappropriately" dressed [7].

2.2 Visual Expression of Individual and Group Identity

One of the most important ways in which the aesthetics of dress are interpreted is in understanding and assigning group identity. In some ways, the individual can be perceived as the intersection of the many groups of which she is a member: explicit groups such as her occupation, age, and socio-economic status, as well as less explicit groups like the kind of trends she adopts, products she buys, and the way in which she wears her clothes. In wearable sensing, a device may communicate group affinities like "handicapped," "sporty," or "high-tech," depending on its aesthetics and context. For example, the wearable volumes shown in Figure 1 may evoke very different group affinities depending on the shape, body location, and visibility of the "device." By assembling the many referential characteristics of her appearance, the observer forms an aggregate impression of this individual's identity. This impression is also heavily influenced by the observer's experience: for example, a young man wearing very tight jeans may be displaying allegiance to a certain trend, communicating to others that he is style-conscious enough to know that this is a trend and confident enough to pull it off. An older observer, however, may not be aware of this trend or that there exists such a group of younger people who all agree that this is a stylish way to dress, and may interpret the tight jeans by drawing on other previous experiences in which men were observed wearing tight jeans. If no suitably similar previous experiences are found, the viewer may perhaps interpret the visual appearance in another context, such as evidence of rebellion, lack of social awareness, or any number of other reasons.

Because wearable systems have not yet achieved widespread adoption, it may be difficult for observers to identify the group representation afforded by a visible device. As such, the aesthetics of the system may be grouped with a nearest-neighbor reference point, by interpreting expressive characteristics that fit a known category (such as the aforementioned influence of color).

In addition to communicating group identity to others, the way we dress also communicates some element of identity to ourselves. The "role" theory of social organization posits that an individual's understanding of how he is perceived by others mediates the roles he believes he is able to perform, and can actually affect his abilities and skills. A 2012 study by Adam and Galinsky [8] found effects in cognitive performance between groups of participants wearing identical white lab coats. The group told that their coat was a doctor's coat performed significantly better than the group told that their coat was a painter's coat. In wearable systems, similar effects can be found. Wearing a medical device may result in the wearer adopting a "sick person" or "patient" role, causing them to reduce their physical activity and restrict their movements in some way. For example, Costa et al. [9] found that patients wearing an ambulatory blood-pressure monitor were significantly less active when wearing the device.

Wearable robotic systems and their applications for neurorehabilitation

Agnès Roby-Brami, Nathanaël Jarrassé, in Rehabilitation Robotics, 2018

Actuators

The actuation of wearable devices must be able to generate a high level of forces and to follow, without perturbing, the human movements that are conflicting objectives. Therefore, soft innovative mechanical transmission and actuation solutions had to be developed: pneumatic, hydraulic, Bowden-cable, or serial elastic actuators, combined or not with conventional electric actuations (review in [7]). In addition, the systems intended to be wearable impose that the power supply (or compressor for pneumatic and hydraulic solutions) should be silent, compact, and light enough to allow untethered use. Wearable systems often combine those diverse technological solutions. In addition, hybrid systems may incorporate functional electric stimulation of certain muscle groups.