# QL-282 - Emerging Medical Sensory Technology

*"The living body is a very complicated system whose function very much relies on sensors"*

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## Introduction

This Quick Look (QL) study identifies Commercial Off the Shelf (COTS) emerging medical sensory technologies that are relevant to the rehabilitation of military and security personnel with combat injuries. The emphasis of this report is on technologies for body measuring, haptic feedback, patient guidance and remote and oblivious body sensing.

There is a wide range of sensory technologies that are used to monitor rehabilitation by collecting real-time data. These data are sensed either by ambient sensors, that measure the patient's activities from a distance, or sensors that are attached directly to the body. In some cases, sensors are even incorporated within the body to closely observe physiological and chemical changes.

From the reviewed literature, it is evident that the technology trend is to develop patient-centric rehabilitation systems that incorporate smart mobile technology with visual analytics features that provide useful information to medics and patients.

This report includes recommendations of sensory technologies for rehabilitation that are adopted within the clinical environment, as well as patient-centric devices that are used away from clinic. Finally, it includes tabular summary of hardware and software specifications, nature of application, cost and training requirements on some of the products currently available.

Key words: *Medical rehabilitation technology, sensory devices for rehabilitation, body measuring and remote sensing health application, haptics and Virtual Reality (VR) rehabilitation, mobile and remote sensing for rehabilitation.*

## Summary

Most modern rehabilitation products use sensory technologies in some capacity. Data collected by sensors is further processed into tangible information to assist rehabilitation. These devices are used in a variety of ways, for example within specialised rehabilitation centres that are operated by trained medics, or adopted for use by the patient independently (these are often stand-alone devices with limited functionality). These patient-centric devices are designed with a view to engage the patient in the rehabilitation process. Gamification [26] is an example of such design where the concept of a game is integrated to encourage its use. This type of rehabilitation device is a contemporary approach to personalised healthcare due to fact that it reduces the cost of rehabilitation and it can also integrate with user-familiar technologies such as a smart phone or interactive TV set. This increases the patient's engagement in the process of recovery, which is an important factor in the rehabilitation process and the patient's health-awareness.

According to a recent report by a consultancy group for future technology investment [1], there is a great degree of interest in sensory technologies due to the growing development in the Internet of Things (IoT) and wearable technology for health related applications. It is also evident that sensory-based data collection and interaction for health applications covers overlapping disciplines such as:

- medicine and pharmaceutical industries to address medical diagnosis and cures as well as injury and disease prevention.
- science and engineering to explore new sensory materials that capture higher resolution data with increased streaming rate.
- usability engineering to craft user-friendly products.

This interdisciplinary aspect is another driving factor for innovative medical sensory rehabilitation systems.

## Recommendations

Information about patients (based on behavioural as well as biochemical sensed real time data) is powerful not only for rehabilitation but also in detecting symptoms earlier before injury or illness occurs. Coupled with this, the ability to access information remotely is particularly valuable for operational situations where potential injuries or diseases can be avoided. Stakeholders for smart medical sensory technology include high tech companies as well as pharmaceutical industries and health / medical / patients' groups who are keen to push these developments to a new level maturity that can be used confidently for many medical areas and particularly in non-clinical environments.

Although some sophisticated rehabilitation systems are now available (see example section), further research is needed to ensure that these are medically valid and in compliance with approved standards before use in medical applications.
Some advocates view these rehabilitation systems as an alternative to or complementary to prescribed medical drugs, although it must be noted that poor design and misuse of information could have counterproductive side effects.

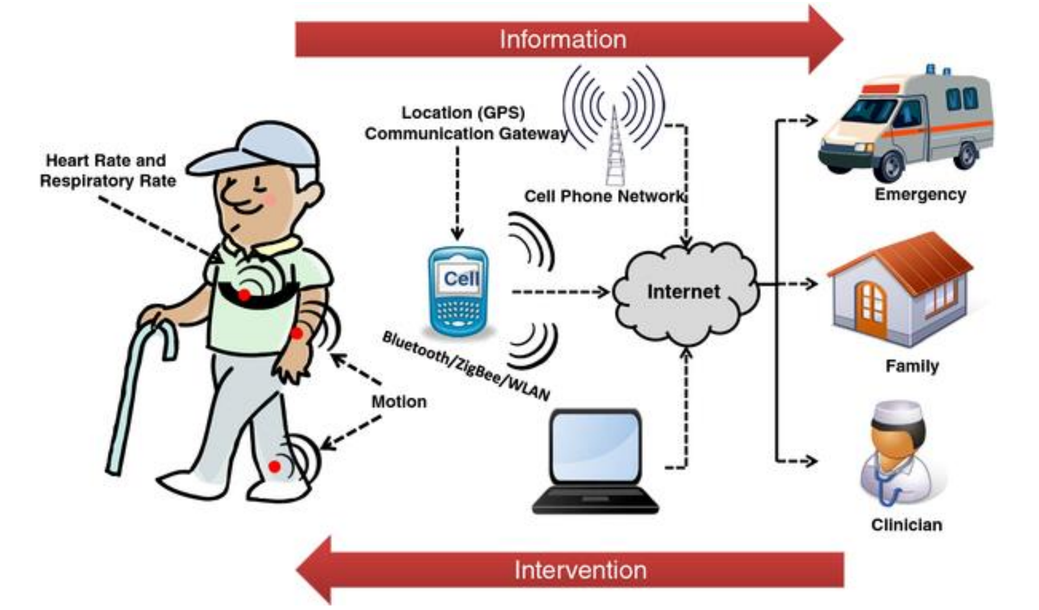



Figure 1: Illustration of a use of sensory technology for a health monitoring system [17].

The recommendation[1] for how these technologies are applied for rehabilitation is summarised below:

1. The clinical rehabilitation environment, where medical sensory technology is adopted, requires a clinical set-up with trained medics to operate it. The sensory technologies relevant to such cases could include the following: visual, auditory, tactile, vestibular as well as other chemical and biological sensors. These are often used as an integrated system. Below are examples of this category:
   - CAREN [2] – This is a rehabilitation system where wearable sensors are attached to the body in order to monitor physical rehabilitation that will help patients to regain loss of movement in lower and upper extremities as well as head and neck. .

[1] note:
a) Regular market analysis would be required if any of recommended technology is considered for adaptation;
b) These recommendations are not based on any field work or practical observations

- Lumee Oxygen Sensing System [34]: This is an example of a body chemistry sensor that is used to monitor a particular body part, such as after injury or surgery (more details are available in the examples section).

2. Patient-Centric Rehabilitation: this category of sensory devices is used by patients independently and often in their living environment. There is no need for any trained medics. It helps patients to have a more active role in their rehabilitation. With remote communication features data can be made available to medics. Recent advances in the Internet of Things (IoT) [28] have also increased the viability of such sensory devices for personalised healthcare and rehabilitation.

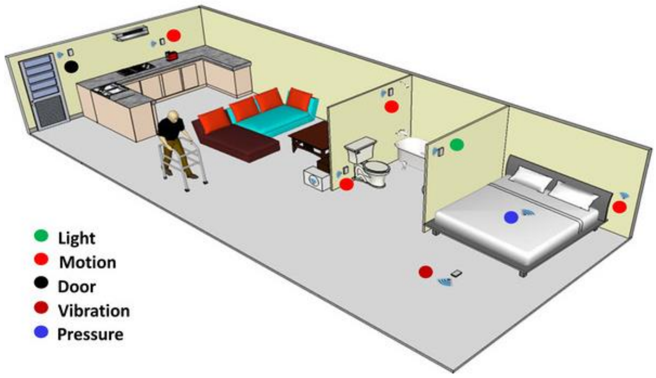



Figure 2. Ambient sensors can unobtrusively

The patient's activity within their living environment can be monitored by sensing movement using pressure and vibration sensors along with location data. Chemical data from the patient can be collected by wearable sensors that monitor heart-rate, oxygen level, blood pressure in specific parts of the body such as the head, neck, torso, spine and back.

The recommended systems for this category are VirtualRehab [7] for neurological and physical rehabilitation such as battlefield Traumatic Brain Injuries; YouGrabber and YouKicker [8] for leg and arm impairments; Tibion Bionic Leg for active robotic battle field injury rehabilitation [11] that includes pressure sensors for help with leg muscle movements; Leap motion controller [13] designed to improve patient movement coordination; MYO armband (from Thalmic )[15] that allows signals from muscles to operate upper and lower extremity prosthetic rehabilitation devices (more details are

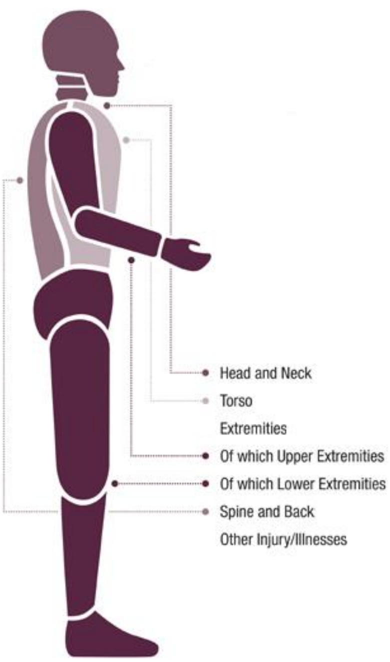



Figure 3. Typical Battle field injuries [27]

in the examples section).

## Background

## What is Sensory Technology?

Medical sensory technology devices are designed to capture data from the patient's body (e.g. chemicals, biological) and his/her activities (e.g. movement of impaired body part, sleep pattern). The output data is generally processed into human readable information or used as an input signal to operate or adjust rehabilitation systems to address the patient's condition.

The sensory technology and its health and medical related applications are evolving quickly for a number of reasons such as:

- developments in the range of sensors capable of collecting chemical and biological data.
- reduction in the size of the sensors, in some cases at a nano-scale that make it possible to capture data from within the body[29].
- increases in scanning resolutions.
- the desire to reduce the cost of rehabilitation.
- an increase in the application domain (rehabilitation and prevention physical and mental disease, monitoring effects of medicine) .
- integration with smart mobile technologies for real time data streaming.
- introduction of the Internet of Things that allows device to device communication and processing without human input to calibrate rehabilitation systems according to the needs of the patient.

The realisation that sensory devices are capable of detecting tiny changes within human body has an immense impact on being able to see, listen, feel and measure data that would otherwise be unavailable. This allows both effective rehabilitation processes and also prevention of injuries or disease. As smart medical sensor technology (including the capture, processing and analysis of data) matures, it is expected that the next generation of rehabilitation care will have a more proactive approach to health, rather than a reactive one that can sometimes struggle to fix damage caused by injuries or illness. It must be noted that these products should be clinically validated before recommendation, in a similar way to the introduction of any new medical treatment. These processes are time consuming and expensive but are clearly necessary.

Most of the current technological products are in the form of wearable items, such as: clothing, watches, phones, rings and eye-glasses that feel natural for patients to use. Sensed data (which can be streamed in real time, different type and have a high volume) can be processed by algorithms which output insightful information. A recent report by IDTechEX [1] on the market analysis of such sensors predicts there will be three billion wearable sensors by 2025, with over 30% of them being new types of sensors that are just beginning to emerge and health-related applications are one of the driving forces behind this. Some of the commonly used sensors are described below:

- **Inertial Measurement Units (IMUs)** that including accelerometers, gyroscopes, magnetometer and barometers. These are self-contained systems that measure linear and angular motion, usually with a triad of gyroscopes and triad of accelerometers. An IMU can either be gimballed or strap-down, outputting the angular velocity and acceleration in the sensor/body frame. They are commonly referred to as rate-integrating gyroscopes and accelerometers. These are often adopted for physical, movement and body balance impairments that are often linked with typical battle field injuries.  Such sensors are adopted in rehabilitation systems such as CAREN [2], ESKO [3] and Mindmaze [4].
    - **Optical sensors** - An optical sensor converts light rays into electronic signals. It is both helpful for sensing a patient's activities as well as capturing images from within the body.  The intrinsic physical characteristics of optical fibre combined with its versatility in remote sensing makes it an attractive technology for biomedical applications. It has been used for optical heart rate monitoring, PPG (photoplethysmography[1]) and pain level measurement that may otherwise not be easy to communicate. Optical fibres are immune to electromagnetic interference (EMI), chemically inert, nontoxic, and intrinsically safe. Their use will not cause interference with the conventional electronics found in medical theatres. Furthermore, electromagnetic and radio frequency signals are not affected by optical fibres, making them ideal for real-time use during diagnostic imaging with MRI (magnetic resonance imaging.), CT (computed tomography), PET (positron emission tomography), or SPECT (single photon emission computed tomography) systems, as well as during thermal ablative treatments involving radio frequency or microwave radiation.
    - **Wearable electrodes** - Smart sensor wearable [30] technology is one of the fastest growing markets in personalised healthcare. These are worn like everyday items of clothing and because of their close proximity to the body, the sensors are able to capture valuable health data with good accuracy.  The processed data

[1] PPG (photoplethysmography) sensors is a light-based technology to sense the rate of blood flow as controlled by the heart's pumping action

can be used by rehabilitation systems to correct the patient's impaired body function such posture imbalance when moving or sitting. For example, the HealthPatch MD [35] with ECG (electrocardiography[1]) electrodes and a 3 axis accelerometer can keep track of heart rate, breathing, temperature, steps, and even detects body position to detect if a person has fallen.

- **Chemical & biological sensors [31]** Chemical sensors differ significantly from physical sensors and the numbers of chemical parameters are almost infinite. The number of proteins in the human body is so high that selectivity or specificity becomes a crucial property of chemical sensors. The human body can manage without senses such as sight or hearing but it cannot function without hormones or neurotransmitters. Biological sensors can be used to sense living organism activities such as data acquisition, signal transmission and processing. This area is relatively unsupported but an example of such a sensor in practice is the Lumee Oxygen Sensing System that senses the oxygen level in the tissue (more details in the example sections)

## Emerging Medical Sensory Technology - Examples

This section gives examples of the emerging medical sensory technology within the context that has been outlined above.

1. **<u>Clinical Rehabilitation Environment</u>**: This is a fully equipped environment that requires large scale set-up possibly with specialist trained medics available to assist in the use of the medical sensory technologies. These often deal with serious cases that require closer monitoring and adjustment of the system to the particular needs of the patients. Examples of such systems are:
   a) **The Computer Assisted Rehabilitation ENvironment (CAREN) [2]** - This is a specialised virtual environment that includes a variety of sensors for visual, auditory, vestibular and tactile data to assist in rehabilitation. It provides clinical analysis, evaluation and registration of the human balance system and uses a VR-enabled set-up to assess the subject's behaviour. This system has been tested in different clinical environments [36, 37]. It has the flexibility to be adapted to a specific patient's needs. It also has added components (such as GRAIL, C-MILL, DynSTABLE and M-Gait [ 38]) depending on the patient's specific needs requirements.
   b) **Ekso Bionics [3]** - It is a therapeutic product designed for patients and their therapists. It helps the patient to regain mobility after battle field or spinal cord injury and aims to get them back on their feet sooner. It uses tactile sensory

[1] ECG (electrocardiography) sensors measure the bio-potential generated by electrical signals that control the expansion and contraction of heart chambers

technologies as well as pressure sensors to collect data for analysis and adjustment as well as diagnosis.

c) **Mindmaze [4]** - This uses motion sensing as part of its virtual reality provision and brain monitoring technology for physical and brain injury rehabilitation. Its sensors have 6-degrees of freedom for head tracking and integrated motion capture to allow interaction with the virtual world using hand and finger-tracking with high resolution gesture recognition. Immersive virtual reality provides a highly stimulating environment compared to traditional rehabilitation treatments. Virtual environments can be tailored according to the patient's preferences and needs, motivating them to maximize their therapeutic exercise training routine. Real-time multisensory feedback also enhances the patient's awareness of their performance. MindMotionPRO [5] is for use in the early stages of combat injury rehabilitation. As an easy to use mobile unit, it is designed with sub-acute rehabilitation in mind. It has the following components:
   - A database of carefully developed immersive virtual reality exercises designed for serious movement impairment.
   - A set of training exercises based on recognized rehabilitation principles that allows one to easily change the required level.
   - Use of gamification [6] [9] that increases patient engagement and encourages longer training time (patients may temporarily forget they are in the hospital).
   - Easy analysis and monitoring of patient performance using time series analysis, ensuring continuity of care.
   - Motion capture technology and analysis: motion capture sensors provide position and orientation to enable real-time mapping onto a virtual character (avatar) that can assume different postures (lying, sitting and standing) irrespective of the environment. In addition, body sway and posture are monitored to optimize the visual feedback to the patient. Post session analysis is provided by the system to track the patient's performance.
   - Neurophysiological Measurements and Analysis: recording of non-invasive electroencephalographic (EEG) signals to investigate multisensory and motor processes underlying movement recovery. It provides continuous brain monitoring during specific goal-directed tasks in the virtual environment and its correlation to movement performance provides objective markers for treatment. It allows the user to switch between virtual and augmented reality modes.

d) **Tissue-integrated biosensors** are used for monitoring multiple body chemistries.
   - **Profusa** [34] is a pioneering developer of tissue-integrated biosensors and has developed implantable biosensors for simultaneous and continuous monitoring of body chemistry. These are aimed at monitoring health status and real time

detection of the body's chemical constituents. The biosensor technology provides a continuous stream of wireless data on oxygen, glucose, lactate, urea, and ion concentrations in the blood. It is placed under the skin with a specially designed injector: each tiny biosensor is a flexible fiber, 2 mm-to-5 mm long and 200-500 microns in diameter. The device is fully integrated within the body's tissue free from metal devices or electronics. Each biosensor is comprised of a bioengineered "smart hydrogel" (similar to contact lens material) forming a porous, tissue-integrating scaffold that induces capillary and cellular in-growth from the surrounding tissue. It has the ability to luminesce upon exposure to light in proportion to the concentration of a chemical such as oxygen, glucose or other biomarker, and measurement of multiple body chemistries will enable monitoring of a soldier's metabolic and dehydration status, ion panels, blood gases, and other key physiological biomarkers. Integrated and mature sensors will provide multiple analyses. The first commercially available technology is Lumee Oxygen Sensing System with the ability to monitor local tissue oxygen. The obvious use is the treatment of peripheral artery disease (PAD), ensuring the oxygen levels are sustained throughout the treatment and healing process.

- **Temporary-tattoo for long-term high fidelity bio-potential recordings** [21] [1] - This technology is similar to the medical procedure of electromyography that records electrical signals through the skin, similar to a skin electrode. This technology is currently moving from research lab to production level. It is capable of monitoring muscle activity for many hours, for a range of medical and other purposes. It can map motions that can lead to many applications such as moving artificial limbs. This technology has many other applications such as such as brain-machine interfacing, muscle diagnostics, post-injury rehabilitation, and gaming. Figure 4 shows an example of electric tattoo.

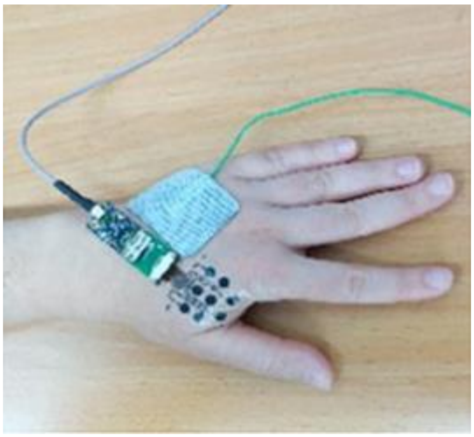


Figure 4. Electric tattoo consisting of a carbon electrode, an adhesive surface that sticks temporary tattoos to the skin and a nanotechnology-based conductive polymer coating, with special nano-topography, that enhances the electrode's performance.

2. **<u>Personalised Rehabilitation Products</u>**: This category of rehabilitation product is designed so that the patient can use them independently. These are often integrated with objects that are already familiar to the user such as a TV set, smart phone or other wearable object. There is wide range of products in the market for this category.

   a) **Automated Exercise Guidance and Progress Monitoring** - These devices are often based on state of the art features from computer or mobile game technology. They use multiple sensors to sense audio, visual and motion data and may give haptic feedback. For rehabilitation purpose, data captured is processed by bioinformatics algorithms. The output is fed back to the user in the form of haptic, visual, audio or simply as text information. Figure 5 shows an example of a body motion sensor. This consists of relatively cheap hardware that can be plugged into a TV screen and connected to Wi-Fi. Some of specific examples in this category are given below:

Figure 5. Microsoft Kinect capture full body motion in real time without the need to attach sensors to the patient's body

   - **VirtualRehab [7]**: This can be used for a variety of neurological and physical conditions including: brain injury, Multiple Sclerosis, Parkinson's Disease, Alzheimer's Disease, Amyotrophic Lateral Sclerosis (ALS); Neuromuscular Disorders (Dystrophies, Myopathies, Amyotrophies, Neuropathies). It is used both by clinics and patients in their own homes. VirtualRehab Body is a suite of gamified therapeutic exercises designed to help retrain upper and lower limb motor functions for a wide variety of neurological conditions. It uses Microsoft Kinect technology (Figure 5) that senses full body motion, sensing in real time without a sensor being attached to body. Figure 6 shows an example of VirtualRehab tools.
   - **YouGrabber** [8]: This product is for patients with hand and finger disorders caused by injuries, Parkinson's disease, multiple sclerosis, spinal cord injury, cerebral palsy, traumatic brain injury and other disorders. It has been used and

Figure 6. Illustration of a use of YouKicker from YouRehab

tested by both in- and out-patient clinics. There are similar YouKicker products for leg and foot coordination. The clinical report [8] lists the following conditions that can be addressed:

- Central nervous system (CNS) disorders or damage, e.g. after traumatic brain injury, stroke, multiple sclerosis, cerebral palsy.
- Spinal cord disorders or damages, e.g. incomplete paraplegia
- Neurodegenerative disorders, e.g. Parkinson's disease, dementia
- Orthopaedic impairments, e.g. foot or leg fracture, surgical interventions
- Cognitive attention and reaction deficits related to disease, age, a volition or lack of motivation [10]

○ **Tibion Bionic Leg for Active Robotic Movement Impairment Rehabilitation [11]**: Tibion Bionic Technologies are developed for people with muscle problems, arthritis, and post-surgery to regain missing strength. A potential use of the Tibion bionic leg is to help those suffering from the residual effects of a paralysis to regain walking skills. These use pressure sensors to synchronise the body movement; simulate corrective movement support; and improve mobility [12]. The key components of the Tibion Bionic Leg (Figure 7) are:

Figure 7. Illustration of a Tibion Bionic Leg

- A pressure-sensing shoe insert that detects and measures the amount of weight a patient is applying to his/her affected leg.
- A computer into which the therapist programs the amount of support to be provided to the patient's affected leg during different tasks.
- Two motors within the Bionic Leg to provide that support.
- An angle sensor in the knee, which informs the computer what the patient is doing or likely to do.

b) **Improve Motivation and Compliance Through Games Technology** - This is a gamification that use multiple sensors to interact with a VR environment. LEAF Motion (Figure 8) is an example such gamification that is designed for rehabilitation of upper limb, lower limb, dynamic balance, coordination and back injuries. It improves the range of movement caused by injuries by strengthening the affected part, improving coordination and cognition response rate.


Figure 8. Gamification products

c) **Wearable Sensor Technology** - Medical wearables feature smart sensors, usually using Bluetooth to connect wirelessly to smartphone, cloud and beyond such as clinics. They use sensors to collect measurable health data, not only for staying fit and active or losing weight but also data that can be used for rehabilitation and injury prevention. Below are examples of wearable sensor technology.

- **MYO armband** [15] from Thalmic Labs measures electrical activity to detect fine movement from the wearer's arm, which allows the user to control a computer (Figure 9). Myo armbands are worn on the upper arm to detect the electrical activity of the muscles. The Myo armband has electromyography (EMG) sensors that directly sense muscle activity and motion, which is particularly useful for operating artificial arms.

Figure 9. Myo armband senses muscle signals to control technology with hand and arm gestures

- **Leap motion controller** [13] tracks hand and finger movement in a small 3D space with a claimed accuracy of 1/100th of mm. Leap Motion is used in a broad range of fields – from physical therapy and special needs accessibility to surgical training. With recent innovations in embeddable modules, Leap Motion is already making it possible for surgeons to access vital medical information while maintaining a sterile environment.
- **Shimmer – Medical grade wearable wireless sensor** [16] is a small wireless sensor platform that incorporates wireless ECG (Electroardiography), EMG (Electromyography) , GSR (Galvanic Skin Response), Accelerometer, Gyroscopic, Magnetometer, GPS (Global Positioning System), tilt and vibration sensors. The range of applications includes stress detection and analysis, psychological arousal and cognitive factors just name a few.

d) **Flexible Stretch/Pressure/Impact Sensors**

- **FeelIT** [23] are flexible, printed sensors with high resolution (sub millimetre) location sensing, low power consumption and a sensitivity scale from milligrams to several kilograms (Figure 10). The printed patch is sensitive to touch. It is

Figure 10. FeelIt: Highly sensitive touch sensing with adjustable sensing range and sub-millimeter location resolution

suitable for physiotherapy and rehabilitation as well as physiological monitoring, touch sensitive surgical tools, gamification and virtual reality rehabilitation applications.

- **Flexible Textile Pressure Sensors** [ 24] [25], from LG Innotek, has the capacity to sense pressure from the entire surface of the sensor and it is bendable. It is made of a highly elastic polyurethane material to fit the body comfortably. It can be applied in telemedicine, for example it can measure the pressure exerted by the body in motion as well as detecting body balance, then information from the sensor can be sent directly to therapists to monitor patient rehabilitation. It is widely used for accurate detection of physiotherapy activities.

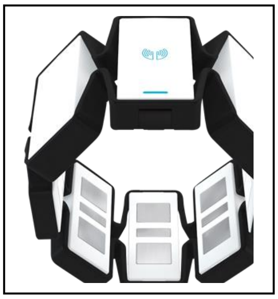
- **StretchSense** [33] is a small, discreet, capacitive pressure sensor (Figure 11). It measures the pressure being applied to the body and can be directly attached to the user or sewn into fabrics. The device can be used to quantify factors such as comfort. Currently it is used for custom pressure sensors in shoes, in motion capture systems, in VR systems for medical training and in rehabilitation. It can be used in conjunction with other devices to make the process of data collection more comfortable for patient.

Figure 11. Illustration of a StretchSense technology.

## Technology Assessment

Specifications for a number of the recommended devices are given below:

**Table 1 – Technology Assessment Criteria**

| Device Name | Myo Gesture Control Armband |
|---|---|
| Manufacturer | Thalmic Labs Inc. |
| Country of Origin | Canada |
| Image | myo.com |
| |  Figure 12: Myo Armband |
| Manufacturer's Description | The Myo armband reads the electrical activity of your muscles to control technology with gestures and motion, hands-free.<br>The Myo armband is changing an amputee's life by giving him control over a prosthetic hand with researchers at Johns Hopkins Applied Physics Laboratory |
| Application | Gesture control armband |
| Category | Input |
| Availability | Widely |
| Cost | $199 USD |
| TRL | Not classified |
| Certification | FCC, CE and Canada Compliance |
| Licensing Constraints | No |
| Connection Type | Non Tethered |
| Communication Method | Bluetooth 4.0 Smart, micro USB |
| Sensor | 9 axis IMU, 8 EMG sensors. See https://www.myo.com/techspecs |
| Weight | Approx. 93g |

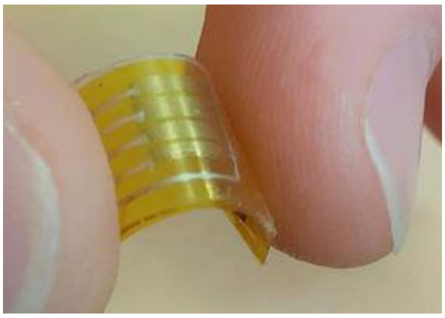
| | |
|---|---|
| Dimensions | Approx. 104mm(l)x10mm(w)x47mm(h) |
| Power | Rechargeable battery - solid state lithium ion |
| Power Consumption | operational power output of -30 dBm to -4dBm |
| Battery Life | Up to 24 hours of continued use, 1 week in standby |
| Connection Type | micro USB for charging, firmware update |
| Communication Method | Bluetooth 4.0 Smart, micro USB |
| Sensor Type | EMG, gyroscope, accelerometer, magnetometer |
| Sensor Accuracy | raw EMG data is streamed at 200Hz, IMU data at 50Hz |
| Sensor Resolution | raw EMG data is streamed at 200Hz, IMU data at 50Hz |
| Latency | raw EMG data is streamed at 200Hz, IMU data at 50Hz |
| Platform Support | Windows, OS X, iOS, Android. See https://www.myo.com/techspecs for list supported devices and operating systems. |
| Application Support | Myo Connect software. See https://market.myo.com and iOS, Android app stores for compatible applications/devices |
| Product Support | See https://market.myo.com and iOS, Android app stores for compatible applications/devices |
| Min Hardware Requirements | See https://www.myo.com/techspecs for list supported devices and operating systems |
| SDK / API | Yes. See https://developer.thalmic.com for more info |
| SDK Language | C++ |

| Device Name | Shimmer3 |
|---|---|
| Manufacturer | Shimmer |
| Country of Origin | Ireland |
| Website | www.shimmersensing.com |
| Image |  Figure 13. Shimmer 3 |
| Manufacturer's Description | Shimmer is a wearable sensor platform that allows easy capture and transmission of body centred data. Depending on how the platform is configured, it can offer a range of kinematic and physiological data, and either log it to the device storage or stream it via Bluetooth to another Bluetooth enabled device like a PC or Android device. |
| Application | Shimmer is an investigational device for researchers and research institutions that can be used to record movement, fitness and personal wellness. |
| Availability | Shimmer is the sole manufacturer of Shimmer products from our facility here in Dublin, Ireland. Products are available via Shimmer website. |
| Cost | €499+ (dependent on number of units and choice of sensors) |
| Certification | CE certified, FCC certified |
| Licensing Constraints | No |
| Connection Type | Tethered |
| Communication Method | Bluetooth |
| Sensor | Motion (Accel, Gyro, Mag)<br>Biophysical (ECG, GSR, EMG, Skin temp) |
| Weight | 22g |
| Dimensions | 53x31x15mm |
| Power | Charging docks / Base |
| Battery Life | Continuously via BT: Approx. 16-20Hrs<br>Logging to a Micro SD card: Approx. 18 Days |

| | |
|---|---|
| Connection Type | Tethered |
| Communication Method | Bluetooth |
| Frequency | Our sensors are capable of a sampling rate of 1024HZ |
| Sensor Type | Motion (Accel, Gyro, Mag)<br>Biophysical (ECG, GSR, EMG, Skin temp) |
| Sensor Resolution | 16-bit resolution |
| Latency | Experimental results have shown the data latency over the Bluetooth channel to be variable. The same statistical distribution for the latency was found for Shimmer-to-Shimmer and Shimmer-to-PC communication over Bluetooth, with a mode of approximately 25 ms and a maximum value of less than 100mS. |
| Display Resolution | 16-bit resolution |
| Platform Support | Windows & Android.<br>APIs in C#, Java and Android, alongside Matlab and LABVIEW Instrument drivers to enable users to develop their own applications with the data output |
| Application Support | Windows – See above |
| Min Hardware Requirements | Development kit, charging dock / base.<br>Electrodes, biophysical leads etc. |
| SDK / API | Consensys Software |

| Device Name | Leap Motion Controller |
|---|---|
| Manufacturer | Leap Motion, Inc. |
| Country of Origin | USA |
| Image | <br>Figure 14. Leap Motion Controller |
| Manufacturer's Description | The Leap Motion Controller lets you use your computer in a whole new way. Reach out and swipe, grab, pinch, or punch your way through the digital world.<br><br>It's more accurate than a mouse, as reliable as a keyboard and more sensitive than a touchscreen. For the first time, you can control a computer in three dimensions with your natural hand and finger movements.<br><br>The Leap Motion Controller tracks your hands at up to 200 frames per second using infrared cameras – giving you a 150° field of view with roughly 8 cubic feet of interactive 3D space. |
| Application | Leap Motion's technology is designed to allow users to control their computers with hand gestures alone. |
| Category | Gesture /Motion Controller |
| Availability | Can be bought on-line |
| Cost | Depends on the retailer. Approximately ~ £50.00. |
| TRL | Unknown |
| Certification | Nil |
| Licensing Constraints | No |
| Connection Type | Non Tethered |
| Communication Method | USB |
| Sensor | Infrared |
| Weight | 281 g |
| Dimensions | 126 mm x 126 mm x 46 mm |
| Power | USB |
| Power Consumption | USB connectivity. Power consumption unknown. |
| Battery Life | N/A |
| Connection | UDB 2.0 |

| | |
|---|---|
| Type | |
| Communication Method | USB 2.0 |
| Sensor Type | Motion |
| Sensor Accuracy | Up to 1/100th millimetre |
| Latency | Nil |
| Platform Support | Windows 7,8, Mac OS X 10.7 Lion, 2 GB RAM, USB 2.0 port, Internet connection, AMD Phenom™ II or Intel® Core™ i3 |
| Application Support | Works alongside existing devices, keyboards, mice and trackpad. Can scroll webpages or switch between apps at the wave of a hand.<br><br>Just plug it into the USB port, download the free software, and you're off to a new dimension. |
| Product Support | Infrared cameras to detect your movement |
| SDK / API | Individual SDK for all platforms listed above |
| SDK Language | Dependent on Platform |

| Device Name | FeelIT Smart Patch Sensor |
|---|---|
| Manufacturer | Feelit Ltd. (A start-up company) |
| Country of Origin | Israel |
| Image | <br>Figure 15. Adherable flexible patch configuration with adjustable form factor and exceptionally thin patch sensor (down to 50 microns). |
| Manufacturer's Description | FeelIT presents flexible touch sensing smart patches with tactile capabilities that match, and even exceed, human fingertip touch sensation |
| Application | Applications include Surgical tools, for assistance in tissue analysis and wearables, for assistance in physical therapy or sports monitoring, or gaming. Also suitable for human-computer interaction and mobile wireless applications. |
| Category | Touch and location sensing |
| Availability | Not yet commercially available. |
| TRL | Unknown |
| Certification | Nil |
| Licensing Constraints | No |
| Connection Type | Tethered |
| Sensor | Touch; motion; pressure |
| Power | Battery (type unknown) |
| Power Consumption | Low power consumption - Piezoresistive sensing technology with proprietary sensor design and processing that lowers readout power consumption by >90% (compared to a conventional 2D array technology). |
| Battery Life | N/A |
| Connection Type | Tethered |
| Sensor Accuracy | Very high tactile resolution and fast readout times to match, and even exceed, human fingertip touch sensation. |
| Sensor Resolution | High resolution touch and location sensing - Highly sensitive touch sensing (20 mg LOD and resolution) with adjustable sensing range and sub-millimetre location resolution. |
| Platform | Fully integrated wireless solution - Customizable platform design enabling |

| | |
|---|---|
| Support | adjustment of the sensing patch configuration and shape as well as the data acquisition HW and SW according to application needs. |
| SDK / API | Individual SDK for all platforms listed above |
| SDK Language | Dependent on Platform |

## Summary of Findings / Conclusions / Future trends

Sensory technology is expanding fast and has been applied innovatively in many areas of medicine. The indications are that this will be the trend for a long time to come. The reasons for this are:

- reduction in physical size and cost of sensors.
- increase in the variety of the sensors that are able to detect different data types, with high resolution and in real time.
- technological maturity in mobile communications and big data analytics that embody Smart Sensing Technologies (SST). SST is becoming a core component of the Internet of Things. This is particularly useful for many medical applications including personalised rehabilitation. Also it is clear from the literature and scale of published work that the future trend will be:
  - Personalised and preventative health technology that will put patients more in charge of rehabilitation after injury as well as helping to prevent illness and injuries. This is made possible by having access to comprehensive physiological and chemical data in real time. The technology will have warning systems to guide soldiers in the battle field and inform medics remotely so that remedial actions can be put in place at the right time
  - Gamification that will use game-like activities to address health-related rehabilitation of physical injuries and mental abnormalities. This engages the patient in the rehabilitation process. Gamification increases health awareness and has been called a “digital drug” that in some cases may replace prescribed drugs.
  - Printed sensors will be used to allow combat soldiers to monitor their body activities both physically and mentally to avoid injuries in the battle field. On injury, data is available to medics who can advise on the immediate action to reduce long term damage before evacuation. Vitaliti by Cloud DX developing Cloud Diagnostics checks for heart rate, respiration, blood pressure, oxygen, movement and temperature that could be valuable to avoid injuries in battle field.
  - Biological and chemical sensors to measure and transmit data within the body that has not been possible up to now. These sensors are in the form a small nano-scale that monitors and reports the body’s readiness for battle field activities. An example at the development stage is the Helius by Proteus Digital Health: the sensor comes in the form of consumable pill that monitors the correct use of prescribed medicine, giving a warning through a smartphone App if it is not taken according to the prescription.

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