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"Wearable electronics", "smart textiles" and "intelligent textiles" are still buzzwords which beg the question: hype or trend? Andreas Roepert, Interactive Wear AG, looks at the electronic devices that permeate more and more areas of our life and are becoming smaller but, at the same time, more complicated. A broad portfolio of functionality supports the people of today who are more mobile, active and health conscious than ever before.

Wearable technologies



'Know Where Jacket' with integrated GPS.
Interactive Wear

Adaptation of design for electronics actually goes without saying: dedicated pockets for cell phones and MP3 players, and cable apertures and ducts are found in a whole range of apparel. Furthermore, the integration of electronics into clothing opens up new possibilities in sport, leisure and our working lives and offers increased convenience for the user.

With the newly developed technologies, the 'cable spaghetti' vanishes, and the electronic devices can be conveniently, comfortably and unobtrusively integrated. They are operated using textile keys which are visible only as imprints and may thus be matched harmoniously into the overall design.

It is in the sporting sector in particular that integration concepts have made their breakthrough. In recent years, with 'adidas one', a shoe has been introduced which adjusts its damping electronically for the ground surface. Nike, in contrast, integrates a step sensor into the Nike+ shoe and cooperates with Apple so as to appeal to the iPod jogging customer.

Furthermore, Numetrex has integrated electrodes into a sports bra so as to relieve women of having to wear an uncomfortable chest band. The pulse signal is transmitted wirelessly to a pulse watch by a small device clipped onto the bra. In the autumn of 2006, adidas and Polar are launching their long promised 'Fusion' project, an architecture in which various integrated sensors for heart rate and step frequency are unified in a single application.

Skiers are familiar with an awkward situation in the ski lift: the cell phone rings

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and you do actually have the time and would like to take the call – but what to do with the sticks? O'Neill provides the solution here. Starting with the snowboard jacket series H1, it is possible to operate a telephone via Bluetooth to allow hands-free speech. It can also be operated with ski gloves. The technology was implemented by Interactive Wear (which emerged from Infineon Technologies in 2005) and set a new milestone in this field. Today, with the H3, the third generation is already on the market.

Commercial applications are being offered by more and more companies in the wake of the MP3/iPod hype. Numerous companies offer integrated MP3 and iPod remote control – sometimes with additional Bluetooth functionality – for various items of apparel. As well as the jackets from Burton, O'Neill, Spyder and Norrona, one can also find iPod gloves from O'Neill and Marmot, and pants from Levi's and Lodenfrey. The integration of music and communication has also found its way into rucksacks and bags, for example from Simpak, O'Neill and JanSport. The Oakley company offers MP3 integration with its Thumb1 and Thumb2 eyewear and Bluetooth headset integration with Razrwire. Motorola and Oakley are showcasing 'O ROKR' vision as a fusion of sunglasses and Bluetooth stereo headphones. The sunglasses are equipped with a Bluetooth receiver which is Stereo Music Profile enabled. Also, some products with light effects are available, like Uranium providing jeans and shirts with integrated LED panels that show a customer's message to everybody.

The new technologies are also finding their way into the field of workwear and protective clothing. The motivating aspect is personal safety. For example, one finds integrated hands-free speaking systems which permit safe mobile communication for a construction worker on scaffolding. A glance at the current prototypes reveals luminous clothing (e.g. from Philips) and a "Know Where Jacket" with integrated GPS (from Interactive Wear). Besides safety, researchers and developers are working on augmented reality solutions which offer assistance with complex operations; BMW, for example, presented a vest for the service technician of the future at CeBIT 2006. In the field of medicine, people are working with the new technologies on solutions that allow convenient monitoring of vital parameters for high-risk patients.

But how are the solutions actually constructed; which technologies are behind them?

Technologies and components

A 'wearable electronics' application combines intelligent microsystems with both electronic and textile components, supplies them with power and sets up the interfaces for textile integration. It consists of several technological system blocks:

- Sensors are used for input and control as well as for determining environmental and body parameters. For example, acceleration sensors and electrodes for measuring heart rate can be fitted for this, as can microphones and light sensors. Textile control elements are a typical application here. These function in principle as pressure sensors, but are constructed from textiles and can be washed. Actuators are virtually the opposite of sensors: they translate signals into actions and can produce heat, light or sound.

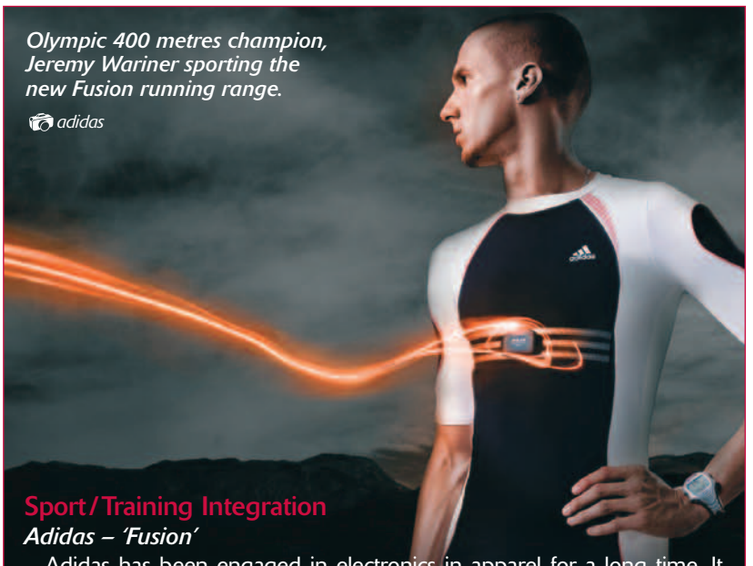
  Sensor-actuator networks, in which distributed sensors and actuators are linked, organise themselves into networks and perform a task cooperatively, have recently gained considerable attention in research. The results are, however, usually limited to simulations and demonstrators. Building on their experience with standard communications technologies for the PAN (Personal Area Network), in which standard communication protocol standards such as Bluetooth or Zigbee are used for communication, researchers are working on methods and technologies to further the transfer of sensor networks into real applications (e.g. in medical engineering). If the sensors and embedded systems are worn on the body as a closed network, then one refers to a so-called BAN (Body Area Network), in which communication can also take place by wireless means.



BMW service vest.
BMW CeBIT 2006

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- An integrated microcomputer implements a wide variety of functions such as music playback, communication via Bluetooth with a mobile telephone, readout of sensors, and the control of actuators. These are called 'embedded systems' and are ubiquitous - whether in cars, mobile telephones or washing machines; 90% of all microcomputers are 'embedded'. A few systems can already be integrated into clothing today. Because of increasing miniaturisation, it is possible to realise simple systems in the form and size of a button or emblem. More complex systems are usually connected to the textile through a docking station, or are constructed to be flat and flexible with the aid of flexible substrates. Researchers are currently working on textile substrates for the assembly of electronics and on printed circuits based on polymer semiconductors; these promise to be the flexible and washable construction elements of the future.
- The individual elements are mostly mounted at distributed points within the item of apparel and must be securely and reliably connected with one another. The connection technology is the key to textile integration and is actually the essence of wearable electronics since it is from this that the unity of electronics and textile arises. The connection implements the power supply and data exchange between the individual components. Both textile character and high reliability are important.
  The connection is subject to considerable stress: both mechanical stresses produced by the washing machine and chemical stresses from cleaning agents and body perspiration. The look and feel of a textile is also important because the introduction of the additional functions to the item of apparel should be achieved in a way that is imperceptible to the user. In recent years, great advances have been made in the development of textile cable materials. Today, for individual connections, as well as crimped connections and solder joints, sewing techniques are also being researched and implemented in prototypes. In a textile setting, both methods are handicrafts for which good quality control is essential. Plug connections have the advantage that connections can be cleanly established and terminated again by the end user. A plug is, however, always a non-textile element that is detectable in a garment, and hence stands out. A better alternative is the classical snap-fastener, especially when only a few lines are required. The connection is durable and can be used inconspicuously directly in the textile. Hence Interactive Wear uses snap-fasteners to attach earphones and microphones into the collar. Light emitting units can be similarly



Olympic 400 metres champion, Jeremy Wariner sporting the new Fusion running range.

adidas

Sport/Training Integration

Adidas – 'Fusion'

Adidas has been engaged in electronics in apparel for a long time. It began with the running shoe "adidas one", with electronically adjustable damping. A sensor measures the hardness of the ground surface and sets the mechanical suspension so that the runner always feels the same degree of damping.

Herbert Hainer, adidas CEO, in a Stern interview, said: "In ten years almost all runners will be wearing intelligent products. It is not exactly pleasant to stretch a plastic band around one's chest. Counting kilometers, measuring heart rate, that will all be on the body. We are working to build the measuring technology into the textiles."

Fusion is the name of the new product series that adidas has developed together with Polar. The running shirts and sports bras are equipped with integrated heart rate sensors. The data from the washable sensors are received by the Polar Wearlink System and transmitted to the Polar Running Computer. Incorporated into the midsole of the Fusion shoes is a motion sensor which transmits data for determining speed and distance to the computer. During running, this computer evaluates all the data from the clothing and shoes and displays them immediately; the data can easily be transferred into a training plan later.

Nike+

Nike was already engaged with electronics before adidas. In 2002, a collaboration with Philips was announced: "Athletes," according to Peter Ruppe, vice president of Nike Equipment, "want technologies which enhance and increase the fun of sport. It is our opinion that no company or combination of companies has yet managed to fully address this requirement. We are convinced that we can move and advance the sports apparel, electronics and sports markets through our partnership with Philips."

The result, however, was rather disappointing and the collaboration fizzled out. But, in 2006, Nike came out with a minor sensation: "We're working with Nike to take music and sport to a new level," said Steve Jobs, CEO of Apple. "The result is like having a personal coach or training partner motivating you every step of your workout."

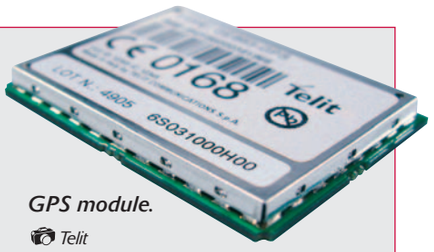
The functionality is, so far, limited to the transmission of motion data from the Nike shoe up to the iPod, for which a corresponding new application has been written. Taking the place of the Polar sports watch, the iPod gives acoustic feedback on the status of the training programme. There is (still) no proper textile integration though. This did, however, allow the solution to be available immediately and cost significantly less than that of adidas-Polar. Further products for the Nike+ range have been announced.

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integrated into snap-fasteners. As an alternative, wireless radio connections can also be deployed. Although they do require their own power supply to be able to operate autonomously, they can permit communication when cable integration is impractical or not possible. The power requirement of a radio node depends on its range and on the quantity of data to be transmitted, and constitutes a fundamental decision criterion for the acceptability of a wireless connection. So it is no wonder that Nokia has launched a new initiative in order to be able to use the established Bluetooth standard even more efficiently for mobile applications. With Wibree, space, power and costs should be saved though a reduction in functionality – and so make it useable for sensor applications.

- Interactive apparel requires power and, since some components are very power-hungry, the power supply is frequently a critical component. Depending on the application, the challenge lies in achieving as long a period of autonomous operation as possible or else a high energy density. The longer the running time and the easier the charging, the better. The dream is of a wearable electronics application which generates the power itself in the way that automatic watches do. This field has been investigated by researchers for years. For mobile applications, one can, in general, rely on either energy sources – and storage – or else on power generation systems. Within expert circles, local power generation from motion or temperature is referred to as energy harvesting. Consider the human body: this already generates in, as it were, "stand by operation" about 100 watts of waste heat. Normal activity results in about 400 watts of power dissipation, and top athletes can emit as much as several kilowatts. Is it not possible to use this energy? In 2002, the semiconductor company Infineon Technologies was engaged in extracting energy from temperature differences, using a thermo-generator. Using this method it is just about possible to power a watch using a small generator – it is not yet anywhere near sufficient for energy intensive applications such as heating or even cooling. The harvesting of mechanical energy at the soles of the feet or from breathing or arm movements has been investigated and the basic techniques ascertained – fundamental work has been carried out at MIT to this end. A popular source of energy is the solar cell. Semi-flexible solar cells for integration into rucksacks or jackets already exist – but they are still very cost intensive to manufacture and function only when sufficient light is available. It is expected that organic solar cells will lead to much more cost-effective solutions in this area within the next few years. In the next two to three years, micro fuel cells should also have found their way onto the market. In comparison to lithium-ion batteries, they can be recharged in an instant with replacement tanks and have a higher energy density. But in practice it is not currently possible to dispense with the good old conventional or rechargeable battery. Whether standard cells (A, AA, AAA) or lithium-ion rechargeables as used in mobile telephony, the technology is proven and reliable.

'Know Where' Applications



GPS module.
Telit

Over the next few years, significant further developments in the infrastructure will lead to positional data being used in all areas of everyday life. The combination of GPS and new satellite-assisted position-determining systems, such as Galileo, makes this data available in even the most remote corner of the earth. At the same time, the growing range of mobile devices with GPS functionality for the mass market will accelerate the development of new applications and content – for end-users and for companies.

GPS-based emergency call systems will roll out worldwide. The European Commission has already launched an e-safety initiative, which encompasses numerous European car manufacturers, telecommunications companies, security authorities and insurance firms. The aim of the project is to reduce the number of fatal accidents on European roads. Consequently, by 2010, all vehicles across the EU will be fitted with an automatic, GPS-based emergency call system.

The healthcare sector provides tremendous potential for GSM/GPRS/GPS solutions. Such applications are particularly appealing for areas with low population densities and a less compact network of medical care provision – such as parts of Northern Europe or Canada. A trip to the nearest doctor can take several hours in these sorts of places. Textile integrated devices that constantly monitor patients' body functions such as pulse or blood pressure can be lifesavers in these situations, transmitting the readings via GSM/GPRS to the doctor.

Projects and products: how to get going?

An increasing number of companies in the apparel business are experimenting with integrated electronic components or are about to release whole ranges of products. Many of the well-known sports and outdoor brands are employing technology and electronics specialists, are setting up multidisciplinary innovation teams, or are entering into cooperation with electronics specialists. Some companies have had great marketing success with this and are following a future-oriented wearables strategy. Wearables do have a very large potential for product differentiation at their disposal. Electronics and textile link-ups offer so many different functions and opportunities that it is hardly possible to set limits on the fantasies of designers. From the simplest applications with

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integration of individual elements such as light emitting diodes or headphones right up to complex systems, a portfolio of the most diverse solutions is at hand.

There are some essential factors which are important for the successful implementation of any product using wearable technologies.

- Attention to the differences in the design and production processes, a joint project plan and timely cooperation between wearables and textile partners helps to fashion the design successfully and to optimise costs.
  The design and production processes in the apparel industry and the electronics industry are fundamentally different. Before production of an electronic device can begin, an extensive, complete test of the system and its components is necessary. In addition, for commercially marketed systems, particular certifications (e.g. CE, FCC) are required. Only after this is it possible to order all the components and manufacture the systems. The cycle from the start of development until production takes at least nine to twelve months as a rule – the delivery time for semiconductor products alone can amount to between three and six months. Specialists in this market must, however, comply with the demands of their customers in the apparel industry, who live from one trade show to the next in a seasonal cycle. While the electronics engineer really needs a definite order soon, the textiles specialist would just like to give samples (which resemble the product as closely as possible) to his distribution channels for testing first, and then have the products delivered around two to three months after ordering.
- Meticulous selection of components as well as of connection and integration technologies determines the quality, robustness, reliability and ultimately the acceptance of the solution. For the simpler projects, it is especially important to pay attention to the quality of the components and their integration into the apparel. There are still large variations in quality and engineering.
  If a complex solution is chosen, the integration and testing of components should be undertaken by specialists, particularly when components from different manufacturers are used. Sometimes a number of specialists are needed to make a good job of integration – and one who understands and coordinates everything. For example, the demonstration model "Know Where Jacket" from CeBIT 2006 is the result of well-organised cooperation between international technology partner companies.
- Well thought through production directives save some surprises. In particular, when you produce an item of wearables apparel for the first time, it is especially important to adhere to certain rules in order to integrate the elements securely and reliably.
- Clear instructions for use, a FAQ, and a good product description facilitate the introduction of the product for distribution. This primarily applies to more complex products and particularly for distribution channels which do not yet have experience in wearable sales.

There is still much to do and learn in making the advantages of wearables applications available to us for different situations. There are, however, so many new developments, technologies and ideas that a few products and their capabilities are bound to surprise and inspire us.

O'Neill Europe – pioneer of wearables

O'Neill was founded in 1952 by Jack O'Neill, who was the inventor of the wetsuit, and is meanwhile the biggest surf brand in the world. O'Neill Europe with its own apparel, footwear and accessory product portfolio has been growing since 1978, when the Netherlands-based company JSI licensed the brand O'Neill from US Headquarters. O'Neill is, besides Quiksilver, reportedly the market leader in Europe in the surf and snowboard apparel market.



O'Neill Europe is again heading the innovation race with the H3 campack for winter 2006.

O'Neill

O'Neill Europe launched the 'Hub1' in 2004, a snowboard jacket with an MP3 player and Bluetooth handsfree set. The jacket, with a docking station for electronic devices and a washable microphone, was developed in close collaboration with semiconductor manufacturer Infineon Technologies. O'Neill has successively broadened its wearable electronics product portfolio from season to season.

- In 2005 an iPod/Bluetooth jacket and a solar-powered rucksack were brought to the market.
- In 2006 there were already five designs: a jacket with just iPod controls, another with the iPod and Bluetooth combination, and also the Fat Controller, a glove with a joystick for wireless remote control of the iPod. The highlight of the season is the multimedia rucksack with iPod interface, Bluetooth, and video remote control.

The H3 Series Video Backpack is leading the innovation for the season. By incorporating a safe and protective housing for a camcorder into the backpack and a separate lens fitted to a flex, the backpack allows the user to record their sessions without removing the camera from the pack. The small, hi-definition lens can be attached to goggle straps or helmets while the basic operating functions for the camera are remotely controlled by a button with two LED feedbacks integrated into the shoulder strap. The pack also incorporates a Bluetooth module for handsfree calling and integrated iPod functionality.