8
Communication apparel and optical fibre fabric display

V L A D A N K O N C A R ,
ENSAIT-GEMTEX Laboratory, France
E M M A N U E L D E F L I N and A N D R É W E I L L
France Telecom Recherche et Développement, France

8.1 Introduction

In the first part of this chapter we introduce basic definitions of communication apparel, describing the process of conception and its main components. Building blocks that have to be used in order to realise these generations of apparel are mentioned and analysed from the point of view of textiles. A classification of innovative, communicative and intelligent functions attributed to communication apparel is also developed.

When analysed individually, the terms 'apparel' and 'communication' indicate well-defined meanings that are closely related to our style of living and our environment. Therefore, our 'apparel' defines our preferences, style or social position, and our 'communication' defines the way we communicate with people, including our family, friends and professional colleagues.

What does the expression 'communication apparel' convey? What kind of communication function is supposed to be integrated into apparel and what is the purpose of this integration? We could say that fashion and clothing styles may explain the basically passive communication expressed by the apparel, for instance colour and patterns.[1] However, this passive communication function of apparel is not the focus of this study. We shall focus instead on the active communication that has to be implemented into apparel in order to enhance the traditional and well-known functions of clothing.

Thus, new forms of communication integrated in apparel, based on the latest electronic devices and data transmission processes, are examined. These should clarify the possibilities for the use of new technology and indicate probable future development related to communication apparel. The area to be investigated is vast and concerns various applications in the fields of health care (e.g. vital functions monitoring, diagnostics, etc.), military applications (combat apparel, injury detection, etc.), leisure (games, multimedia, etc.), business and many others. Nevertheless, all of these applications have a common point – the integration of electronic systems into textile supports.

After covering this step, we will analyse various emerging technologies which allow the integration of electronic devices into garments and textile accessories. Finally, it is important to note the distinction between wearable communication and 'wearable computers', which are not incorporated into the clothing itself, but transported as objects. Wearable communication also differs from 'intelligent clothing', which reacts to exterior or physiological stimuli to regulate and control the user's well-being, like the vitamin C distributing T-shirt, for example. In the second part of this chapter, a new approach to the design of flexible textile displays, simplifying the concept and overcoming the drawbacks of liquid crystal display (LCD) or cathode ray tube (CRT) video screens (rigidity, volume and weight), will be proposed. In addition, a display based on fabric made from optical fibres and classic yarns is described. The fibres are first specifically processed so that light can scatter throughout the outer surface of the fibres, resulting in a transversal restitution of the light. The diameter of the fibre section can be reduced to 0.25 mm, enabling extremely thin and light fabrics to be developed.

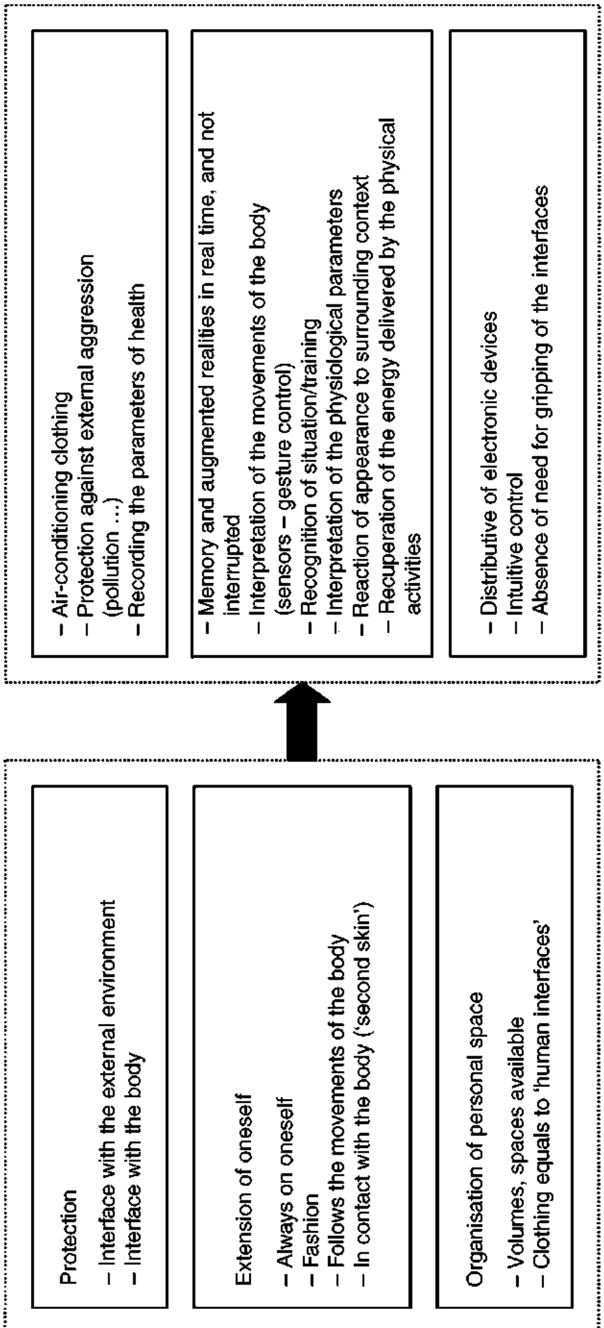
8.2 Communication apparel

Initially, and from a purely technical point of view, the concept of communication apparel may be perceived as the result of a convergence of two industries: textiles and electronics. The miniaturisation of electronics makes it possible for people to carry with them all kinds of devices, qualified as 'portables', with functions ranging from leisure (Walkman, MP3, portable television), communications and information management (mobile phones, personal digital assistants) to health (pacemakers, physiological sensors of parameters).

In another area, the textile industry has made considerable strides in the field of high value-added textiles, mainly in the sectors of high-performance textile and fibres. The use of new materials and the development of new structures and integration processes make it possible to develop supports able to convey information while being mostly based on the properties of electric conduction. These new achievements in the textile industry enable electronic devices to be directly integrated into the structure of textile, therefore modifying the functionality of the apparel. Besides the main functions of apparel, which are protection and passive communication, the clothes become the second skin[1] or an interface with specific functions between the individual and his or her environment.

8.2.1 From basic clothing to new communication apparel

It seems appropriate to examine first the traditional functions of clothing in order to be able to detect the latent needs that could be met by adding intelligent and



8.1 Intrinsic functions of clothing and new concepts.

communicative functions. Figure 8.1 summarises those traditional functions in three main areas: protection, extension of oneself and organisation of personal space.

More and less futuristic projections are given in the second part of this figure on what new functions the clothing of tomorrow could have. All of these concepts can be linked to the intrinsic functionality of clothing. The majority of these new functions are technically feasible today, but require the contribution of various technological specialities (textiles, electronics, telecommunications) according to the clothing's so-called 'intelligence level'. A classification of these new types of clothing is proposed in the next section.

Innovative high-performance textile fibres, yarns and fabrics, combined with miniaturised electronic devices, enable several intelligent functions to be incorporated into apparel. Figure 8.2 shows the stages of development that lead to the elaboration of communication apparel, including the inclusion of telecommunications functions. This figure also classifies apparel in terms of intelligence and communication. All of the technologies used in the process of elaboration (high-performance textiles, electronics, communications and telecommunications) are related to blocs describing the properties that can be useful in the conception of communication apparel. All of these technologies add new functions to the communication apparel, leading to changes in the way we define this apparel. The properties of intelligent and communication apparel, and their potential targets and applications, are detailed in the next sections.

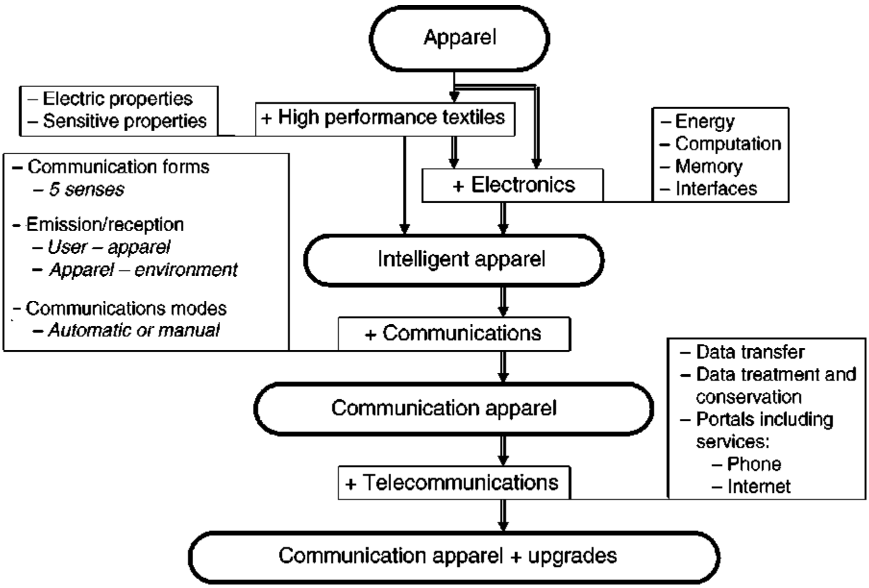
8.2.2 Intelligent apparel

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

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

Finally, all intelligent clothing can function in manual or automatic mode. In the case of manual functioning, the person who wears the clothing can act on these additional, intelligent functions, while in the automatic mode the clothing can react autonomously to external environmental parameters (temperature, humidity, light).

Communicative clothing can be perceived either as an extension or as the next



8.2 Apparel evolution.

generation of intelligent clothing. Although all clothing communicates intrinsically by virtue of its appearance, the type of communication referred to here is that of information coded and transmitted by means of electronic components in the clothing. In addition to the first examples of the integration of portable telephones and miniature PCs, many applications are being studied and have yet to be imagined. Communication can indeed be achieved between the clothing and the person who wears it, or between the clothing and the external environment and other people. In both cases, 'communicative' clothing refers to any clothing or textile accessory that receives or emits information to or from the structure that composes it.

8.2.3 Potential targets and applications

Everyone wears clothing, and most people are concerned with the appearance of communication apparel. However, needs will be different within any given group of people. Let us simply note that the broad, principal topics are:

- professional[2,3] (the need for 'free hands' functions, safety, data exchanges)
- health care[4] (monitoring, training, remote diagnosis)
- everyday life[5] (telephony, wellness)
- sports[6,7] (training, performance measurement)
- leisure (aesthetic personalisation, network games).

8.2.4 Technical elements enabling production

Previous sections have described communication apparel as an extension of the functionality of intelligent clothing. A study of the various technologies involved in the process of producing intelligent clothing can help to anticipate the new uses and new communication services that could be added to clothing. It is therefore advisable to have a vision of the various techniques likely to confer an unspecified form of intelligence on clothing.

In Fig. 8.3, the various stages concerning the design of new communication apparel are shown with building blocks (peripherals, processing data, connectors and energy) that have to be utilised in order to realise new specific functions. These building blocks are obtained using electronic components or textile electronics combined with technological and integration processes. Finally, the building blocks for several important properties are given. In the following sections the building blocks for integration are developed.

8.2.5 Various building blocks for integration

The second column of the table in Fig. 8.3 shows the classification of various electronic parts that can be included in communicative clothing, according to four principal recurring topics: peripherals, processing data, connectors and energy. A short description of these components is provided below, in order to understand better the objectives of research currently being undertaken on electronics 'related to oneself'.

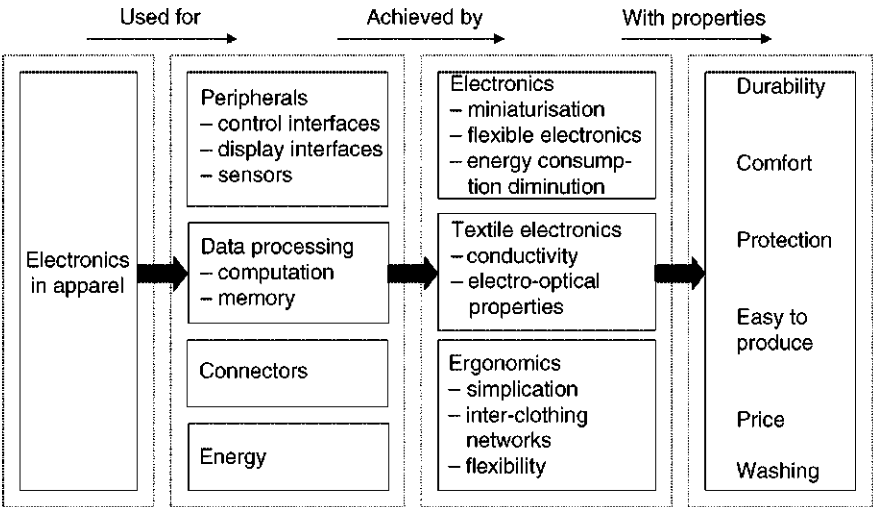
8.2.6 Peripherals

The main peripherals supposed to be used in communication apparel are mentioned and quickly analysed in next few paragraphs.

Control interfaces – near the 'human interfaces'

The use of clothing to support control interfaces is interesting because the control interfaces can be close to the parts of body that are concerned,[8,9] for example, earphones in a collar or a bonnet, a microphone in a collar or a keyboard applied to the sleeve of a jacket. Another interesting example is, of course, voice recognition.[10–13]

The ergonomic adaptation to clothing of all of these control interfaces is also very important. In contrast to certain miniaturised communicative devices, clothing has a greater surface area, which enables it to offer more functionality. For example, the small keyboard of a mobile phone that fits in the palm of one's hand becomes much more readable when transposed to the surface of a piece of clothing that is three times larger. On the other hand, the lightness and flexibility that also



8.3 Technology and constraints of electronics integration into apparel.

characterise clothing implies a need to redefine the forms and materials employed for these new interfaces. New properties guaranteeing resistance to wear and to washing must also be taken into account.

Sensors

Since clothing accompanies every body movement and is sometimes in direct physical contact with the person, it has become an ideal physical support for translating and interpreting human activity by means of sensors. Clothing could be used to detect different actions, in particular the recognition of gestures, in order to facilitate certain commands that are intuitive, as with the automatic release of a phone call when one moves the collar of clothing to the ear.[14,15] Moreover, when these sensors are associated with computing and with the control unit, they may allow the recognition of situation and context for a better interpretation of reality.

Sensors in communicative clothing could also be used as psychological sensors for various parameters. This term refers to the sensors used to record health or person parameters in a broad sense. The applications rising from the use of these sensors are numerous. We can, for example, use sensors to provide a physical performance analysis of an athlete, or to conduct a patient medical follow-up in real time.

Interfaces of information restitution

In many applications, it is necessary to display or reproduce the information produced by communicating systems integrated into clothing. Therefore, traditional interfaces such as displays, screens or loudspeakers have to satisfy the same ergonomics and mechanical resistance criteria as those quoted in the case of control interfaces. Concerning colour liquid crystals screens, for example, the aspects of rigidity, weight and consumption, which characterise them at the present time, have to be adapted. Solutions containing microscreens in glasses or using technologies, including flexible supports, have begun to appear.

In addition, the proximity of clothing and textile accessories to the natural human senses opens new possibilities for the transmission of information. Visual and auditory ways of collecting information (such as screens and loudspeakers), which are today largely developed because they do not require direct contact with the user, could soon be joined by tactile and olfactory methods. The T-shirt with a collar that translates environments by diffusing a combination of perfumes is about to leave the realm of science fiction.

8.2.7 Data processing

The material supports of memory, computation and data processing (RAM, hard disks and processors) will certainly not evolve much in the short term unless they do so in the direction of miniaturisation. Even if developments are achieved on flexible substrates, they remain fragile and require partly rigid protection in order to be integrated into communication apparel. However, their integration has become entirely possible, as seen in the incorporation of a micro PC into the loop of a belt. It is also possible to imagine that only a small quantity of information could be processed locally in communicative clothing, while more complex functions and more significant memory capacities are handled by higher powered remote servers. This difference between local and mass treatment involves the development of specific algorithms, as is the case for intelligent vehicles.

8.2.8 Connector industry

Connection problems are another major issue in state-of-the-art communicative clothing. The principal question is how to transport information and energy between the various components of the electronic system with optimal efficiency. The concepts of weight distribution and ergonomics must be taken into account in distributing the various components on various zones of the body.

Diverse techniques of wireless transmission exist; for example, infrared or radio operator waves using various standards (IEEE 802.11, Bluetooth). If these modes of transmission are to free communicative clothing from the need for physical connections, several additional constraints must be taken into account. For example, the energy consumption necessary for their operation may be important. Moreover, when it is a question of simple information transport (such as an open or closed contact or something similar) or of energy transport, wired connections become indispensable. The wireless connections mainly have to be used to connect the user to the external environment. In addition, it seems interesting to have only one energy source distributed to the disparate electronic interfaces, thus allowing better energy management. On the other hand, each electronic interface could have its own computation and storage capacity, which would allow resources to be allocated and weight to be distributed.

It is important to examine the problem of control and the centralisation of information restitution. In fact, to be able to manage all of the functions of a complex communicating device, it is necessary to centralise outgoing controls and incoming information on a single interface. This means that accessing emails or finding a direction on a cartographic site, for example, must be done on a single screen.

8.2.9 Energy

Autonomy in energy is still a main handicap of the majority of mobile electronic devices. Many users of wireless devices have no doubt dreamt of never having to reload their mobile phones. Even if electronic circuits require increasingly less energy, new possibilities appear and create an additional need for energy (a larger screen size implies a need for greater power consumption).

Even in the case of communication apparel, autonomy versus weight and volume is once again a compromise that must be made. Battery technologies evolve (e.g. lithium–polymer) but, unfortunately, the batteries are still often the heaviest part of portable devices. The advantage of communication apparel is that the weight distribution in clothing will make it possible to be partly freed from this constraint.

Another interesting alternative seems to be the use of renewable energy sources. Solar energy and wind are relatively poorly adapted to clothing because they require large surface areas to be truly effective. On the other hand, many studies have been carried out on techniques that will make it possible to recover the energy released by the physical activity of the human body during the day. And, once more, clothing is an ideal support for these new recharging systems.

8.3 Optical fibre fabric display

Several different projects dealing with flexible displays and screen development have been carried out over the past decades. The final objective is to obtain sufficiently bright and flexible displays in order to facilitate their integration into communicative clothing. Different approaches have been developed involving new textile materials or using the optical fibres in the textile structures. These approaches are discussed in the next sections.

8.3.1 Textile-based flexible displays

There are several approaches to textile-based displays. The research project developed at Auburn University[16] deals with photo-adaptive fibres for textile materials. Moreover, the aim of this project is to develop photo-adaptive fibres that can undergo photo-induced reversible optical and heat reflective changes. Early on, thin and optically transparent polymer films were prepared to study the kinetics of particle evolution occurring in photosensitive fibres. The films were optimised for speed in metal particle formation and were prepared exclusively at high light intensities. These films will be used to study the chemistry of interfacial regions, which seem to have similar properties to the fibres. This approach will then be generalised to produce photo-adaptive fibres in order to make flexible displays using this type of fibre.

Another very interesting research project, in the field of 'chameleon fibres', has been developed at Clemson University's School of Textiles.[17] The aim of this project is to create modifiable colour fibres and fibre composite structures. This is supposed to be accomplished by incorporating molecular or oligomeric chromophoric devices capable of changing colour over the visible portion of the electromagnetic spectrum into (or onto) fibres. This is done by the application of a static or dynamic electrical field. Deliverables envisioned for this type of material include wall and floor coverings that change colour and also 'smart' and communicative clothing with flexible displays. Research on this subject has been conducted in a complementary manner in the laboratories of Furman University, Clemson University and the Georgia Institute of Technology.[18] Colour change is due to the absence of specific wavelengths of light, which, owing to structural changes, will vary with the application of an electromagnetic field.

Electrically conductive fibres can be used to provide a source for generating the electrical field necessary for colour change. Films also have the potential to be applied directly as coatings or polymerised directly on fibre or textile substrates by *in situ* processes.[19] The electrical field strength necessary to bring about dynamic colour change will depend on the choice of oligomer or molecular species, either attached to the fibre or to the surface of the film or embedded within the matrix of the material. A colour change from green to light blue has already been demonstrated for a film containing an oligomeric species in a small applied electric field.

The Visson company has also recently developed display prototypes based on a 0.2 mm thin textile fabric.[20] The display is an assembly of wire conductors woven in an X –Y structure, in order to create a rows-and-columns electrodes network. Each one of these conductive fibres is covered with a very fine layer of electroluminescent material. By addressing an electric voltage to one column and one row simultaneously, the electric field created at the intersection of the corresponding fibres causes electroluminescent material to be emitted at this point.

Some interesting studies also deal with nanocomposite fibres that could be used to develop the flexible displays. The project is the development of biphasic fibres with properties that leapfrog those of the matrix polymers. For example, improved high-temperature mechanical performance, useful optical properties and electrical or barrier properties of these fibres will have a major impact on titre reinforcement, electro-optical devices and other applications.[21]

8.3.2 Optical fibres in textiles

Optical fibres are currently being used in textile structures for several different applications. They are first often used as sensors exploiting the Bragg effect. At The Hong Kong Polytechnic University, Tao has developed several very important applications using optical fibres to measure strain and temperature in composite structures.[22–25] These fibre optic sensors have also been used in smart textile composites.[26] Actually, fibre optic Bragg grating sensors are attracting considerable interest for a number of sensing applications[27,28] because of their intrinsic and wavelength-encoded operation. There is great interest in the multiplexed sensing of smart structures and materials, particularly for the real-time evaluation of physical measurements (e.g. temperature, strain) at critical monitoring points. In order to interrogate and demultiplex a number of in-fibre Bragg grating sensors, whether or not they are in a common fibre path, it is essential that the instantaneous central wavelength of each sensor can be identified.

The research team of Jayaraman[29] at Georgia Tech developed a smart shirt called the Georgia Tech Wearable Motherboard™ that uses optical fibres to locate the exact position of a bullet's impact. Among other interesting functions, this property of location enables a soldier or policemen to carry out health and vital function analysis in a combat situation.

In the present study, optical fibres in textile structures are used to create flexible textile-based displays based on fabrics made of optical fibres and classic yarns.[30–32] The screen matrix is created during weaving, using the texture of the fabric. Integrated into the system is a small electronics interface that controls the LEDs that light groups of fibres. Each group provides light to one given area of the matrix. Specific control of the LEDs then enables various patterns to be displayed in a static or dynamic manner. The basic concept of flexible display is described. It includes the weaving phase, the optical fibre processing procedure that creates the pattern matrices, the electronics interface that controls these matrices and several applications of flexible displays. The two main interesting characteristics of this new flexible device are its very thin size and the fact that it is ultra lightweight. This leads one to believe that such a device could quickly enable innovative solutions for numerous applications.

8.3.3 Optical fibre flexible display (OFFD)

In this section, the process of conceiving and realising an optical fibre flexible display is discussed in detail.

Weaving of optical fibres

Poly(methylmethacrylate) (PMMA) optical fibres present a rigidity and a fragility that are superior to the majority of traditional textile fibre threads and filaments. A good compromise must be obtained between a too significant section diameter synonymous with rigidity, and a too small diameter that induces a low shear resistance and a loss of light intensity. Fibres of diameter of 0.5 mm were retained to make the first prototypes. Tests on fibres with a diameter of 0.25 mm were carried out, but developments in the process of weaving are still required to ensure sufficient fabric resistance in bending.

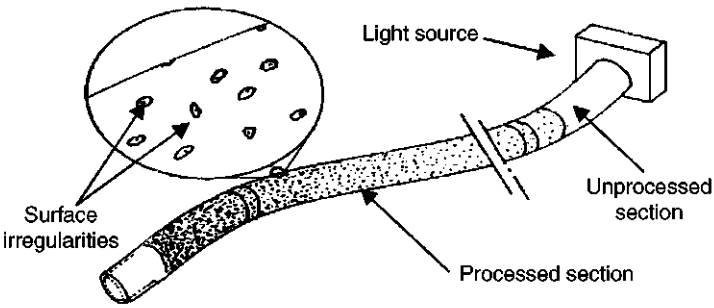
Weaving is carried out on a traditional 2D loom. The optical fibres can be weaved or placed in a chain, in addition to other kinds of yarns. Therefore, it is theoretically possible to obtain an optical fibre X–Y network. However, this would present several disadvantages:

- The fabric would be extremely rigid and the grid (and thus the resolution) not very dense because of the relatively high radius of curvature of optical fibres.
- Constituting an optical fibre chain is very long and very expensive.
- The resolution would be tiny if one refers to the matrix processing described below.
- It is also possible to note that a 3D-structure in weaving would not bring any advantages.

Thus, the initial plan was to realise a fabric comprising optical fibres for wefts and silk in chain. Other natural, artificial or synthetic yarns could also have been retained to constitute the chain. The choice of yarns for the chain must nevertheless be guided by the aim of achieving good flexibility in the fabric, fine titration and an improved capacity to diffuse and reflect the light emitted by optical fibres for better legibility of information. Moreover, different textile finishings are being tested, either in pasting, or in coating, to guarantee grid stability and to enable optimal light emission intensity and contrast.

Display matrix design

The screen comprises a number of surface units, which can be lit individually. The principle of operation consists in conveying to each ‘pixel’ a light source emitted from one side of the fabric by one or several PMMA optical fibres with discrete index variation. Each ‘pixel’ is directly formed on optical fibres while transversely making a spout of light at this precise point on the fabric. This is made possible by a patented process of fibre surface mechanical attack invented by a French company.[33] The process consists of generating microperforations that reach into the heart of the fibre (Fig. 8.4). The remainder of the optical fibre, which did not receive any specific processing, conveys the light without being visible on the surface. The diameter of the fibre section can be as little as 0.25 mm, providing extremely thin and light fabrics.



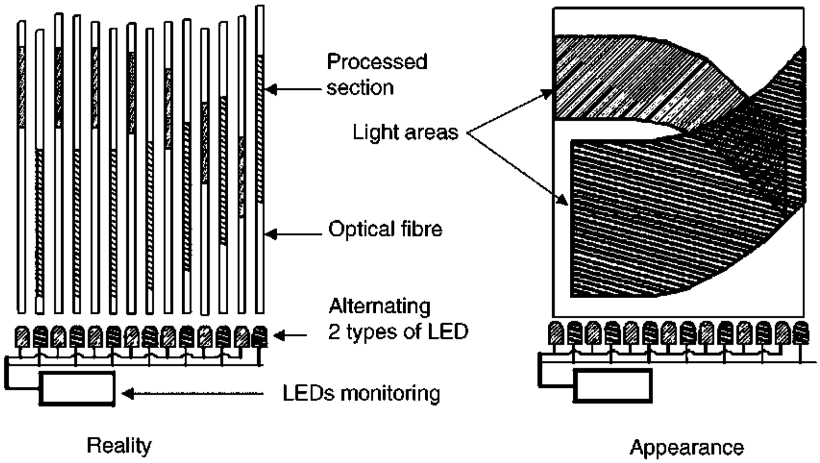
8.4 Optical fibre with multiple point lateral illumination.

Up to now, three existing methods have been available to light ON and OFF static patterns on the fabric (texts, logos and scanned pictures):

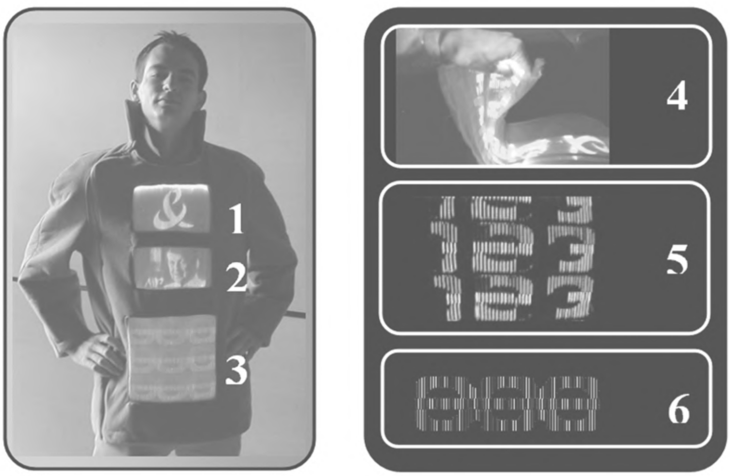
- According to the first method, a basic fabric is used. The lighting zone to be processed, comprising optical fibres, is delimited by a stencil key. The picture remains static – with eventual colour changes – but can offer quite a high resolution (Fig. 8.6, details 1 and 2).
- In the second method, the zone to be lit is formed during weaving on a Jacquard loom before being processed. The remaining, inactive fabric is made up of the floating fibres on the back of the fabric.
- In the third method, a two-layer adapted basic-velour fabric is used that makes optical fibres as visible as possible, but with sufficient consistency of fabric structure. Before the weaving process the optical fibres are chemically treated, enabling the specific dynamical lighting zones to be created.[32]

These techniques had to be adapted in order to generate variable information on the same fabric zone, by creating specific weaving armour and an adapted lighting control. The process described below refers to a matrix that makes it possible to display a great deal of basic information, such as texts, logos or other patterns, in a static or dynamic way.[33, 34]

Since the display can only be driven according to columns made of a single optical fibre or groups of fibres (see page 166), lines had to be artificially created. Taking the example of two superimposed patterns to be lightened on the same column, the principle consists of alternating two consecutive weft fibres, one being intended for the first pattern, the other one for the second pattern. Each one is processed on a precise section in order to re-emit light at the place concerned (Fig. 8.5). The principle is the same for three superimposed patterns, taking one fibre out of three for each pattern. By adopting a sufficiently tight weaving, a visual impression is given of full, enlightened zones. Chain wires will be able, according to the material and texture that compose them, to contribute to diffuse the light



8.5 Two independent light areas superimposed on a single piece of fabric.



8.6 First prototype at France Telecom Recherche et Développement (FTR&D) using an optical fibre fabric display.

towards the dark zones between enlightened segments. The number of rows to be produced seems limited by the technique, insofar as, on the same unit zone, one quickly obtains more dark zones than enlightened ones – in theory starting from three lines. The appreciation of the definition will then be done according to the size of the screen and the number of pixels in addition to the distance from which people watch this screen.

Various light sources can be used to feed the matrix. The choice mainly depends on both the number of fibres connected to each source and on the level of power consumption. For the first prototypes, high luminous light-emitting diodes (LEDs) that are 3 mm in diameter were used. LED technology has many advantages, as diodes can be easily driven by electronics under low voltages (2–4 V, depending on the colour). Therefore, many 'light effects' can be generated on the display, such as flashing or varying the intensity of the light, providing all kinds of animated 'movies'.

Figure 8.6 shows the very first OFFD, which was carried out in a jacket. It comprises a screen matrix specially designed to display, on one line, three 60 mm × 60 mm alphanumeric characters, each made up of three 'rows' and three 'columns' using 0.5 mm diameter optical fibres and a 7 fibres/cm width density (Fig. 8.6, details 3, 5, 6). Each 'pixel' made up of four fibre segments is controlled by one LED located in the lining of the cloth, on one side of the OFFD. The colour of the 'pixels' is determined by the corresponding LEDs.

On this prototype, it should be noted that OFFD offers another possibility. If, on the one hand, the definition is limited by the number of rows, on the other it is possible to repeat the same line of characters or patterns on the fabric in the direction imposed by optical fibres (Fig. 8.6, detail 5). If repeating the same text can appear useless, the fixed or animated pattern reproduction can be utilised for purely decorative applications, for example, to create a mural tapestry adapting its colours to the clothes worn by the occupants of a room.

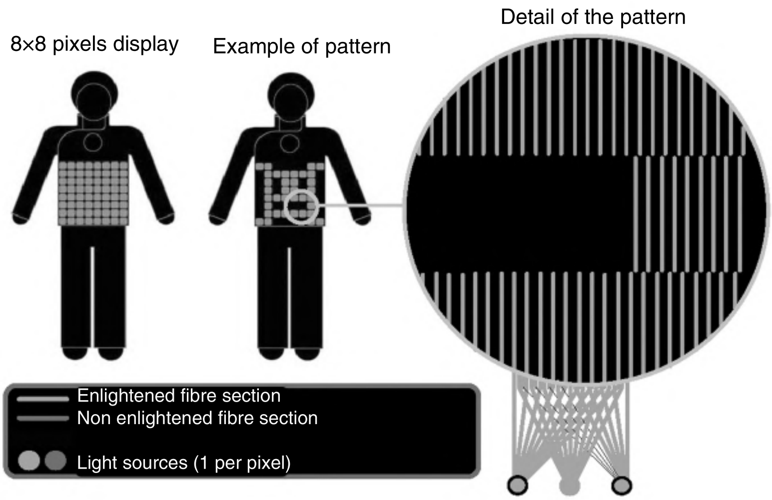
The next step in the development of OFFD technology was to increase the density of the optical fibre weave as the purpose was to create more independent 'rows' (see Fig. 8.5) in order to display more than just alphanumeric characters. A second prototype shown in Fig. 8.7 and Fig. 8.8, was designed to match other conventional display matrices. This new display is made of eight rows and eight columns, and runs according to the same principle as for the first prototype (Fig. 8.7). Animated 'movies' are, of course, not represented in this paper, but some static illustrations of patterns that have been made possible are given in Fig. 8.8.

Figure 8.9 shows two prototypes with a display of 8 × 8 pixels that have been realised recently. The first is a bag and the second a communicative jacket. Explanations and several properties of these new prototypes are given below.

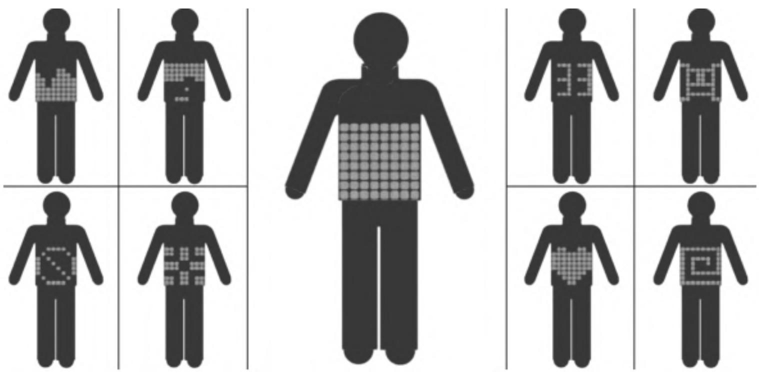
Optical fibre screens provide access to simple and animated visual information, such as texts or pictograms. It is possible to download, create or exchange your own visuals via the appropriate internet gateway. The sending of images or text using wireless technology from a computer or a mobile internet terminal to an article of clothing is also envisaged.

The main functions of the new prototypes are:

- to 'be seen', for security, publicity, games or aesthetic purposes
- to show one's affiliation or support for a group



8.7 Second prototype of OFFD at FTR&D.



8.8 Examples of patterns on the 8 × 8 matrix.

- to personalise one's clothing according to the latest fashions
- to communicate, or exchange information or to signpost advice.

The interests and advantages of the concept are:

- the ability to create and download animations from a fixed or mobile internet gateway to an article of clothing or a clothing accessory
- to animate a forum online
- to manage information on one's clothing in real time.

8.9 Recent prototypes with an 8 × 8 matrix.

8.3.4 Electronics and telecommunication services

The optical fibre matrices developed in the previous section are electronically controlled in order to display different characters and patterns in a static or dynamic way. A keyboard (Fig. 8.10) integrated into the clothing is used to control the display, including several functions: eight preset 'movies' are stored in the electronics memory and can be played in different modes, such as setting up the screen light intensity or interaction with sounds and gestures thanks to specific sensors, and so on. In this prototype, light and small batteries ensure two hours of operation time.

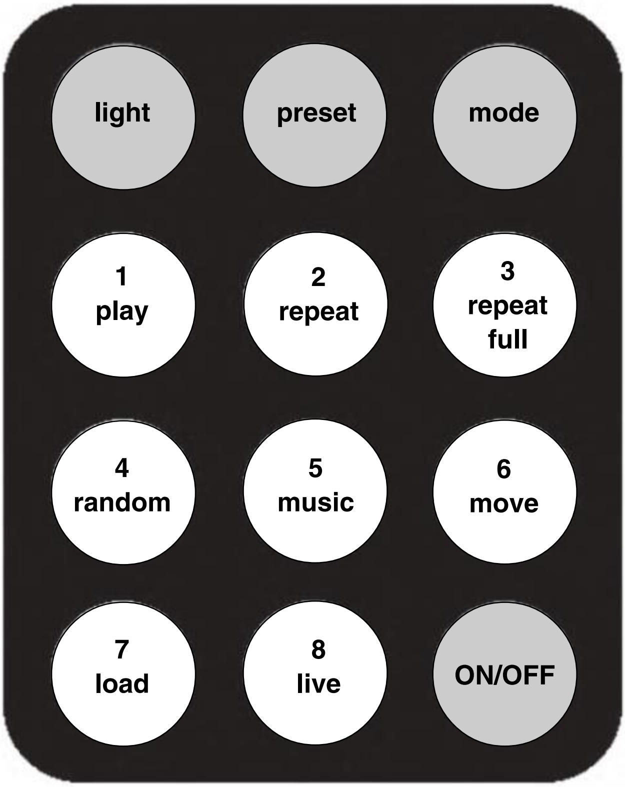
Telecommunication services are shown in Fig. 8.11. The development of this prototype also includes an important software component that allows the user to create his or her own patterns and movies online, using a PC or mobile device.

Because the device is connected to the internet, people can edit the presets and even get new ones already available from a password-protected database.

8.3.5 Flexible display application

Research on the design and development of flexible displays based on optically treated fibres has opened up new frontiers in fields such as smart and communicative clothing, car equipment and home equipment and decoration. The broad range of applications for flexible displays in a variety of segments is summarised in Table 8.1. The table shows a brief overview of the various applications and target populations that could use this technology.

Leisure/business: OFFD can be used as displays for different kinds of mobile phones, personal digital assistants (PDAs), wearable computers and other portable electronic devices. In the fashion industry, different types of fabrics based on



8.10 OFFD remote control.

flexible display technology will open up new horizons for fashion designers and creators.

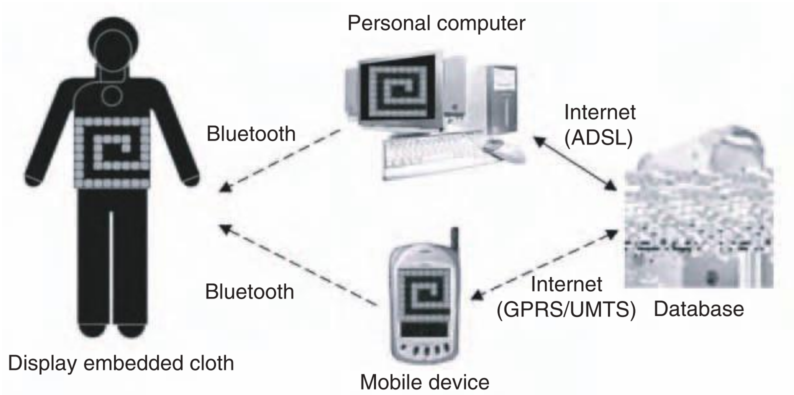
Public safety: There is enormous potential for firefighting and police applications that display information and warnings on clothes. Therefore, this new functionality increases the personal safety and ability of these people to operate in remote and challenging situations.

Car industry: Many applications of flexible display technology are possible in the car industry. The interior equipment of a car contains many flexible elements that can be used to display relevant information.

House/buildings: Decoration and intelligent houses (buildings) need different flexible support for information, drawings, pictures and lighting. In the case of applications for houses/buildings, the problem of energy supply is easy to resolve.

8.3.6 Future investigations

Existing technologies for weaving and specific processing of optical fibres have been adapted by creating a matrix within the fabric and an electronic control



8.11 Telecommunication services. ADSL = asymmetric digital subscriber line, GPRS = general packet radio service, UMTS = universal mobile telecommunication system.

network of LEDs has been developed accordingly to produce an extremely fine, flexible and bright textile display. The structure and the textile materials used suggest a new approach in the field of displays, and more particularly, flexible displays. Generally, textiles have all the basic tools, which are adaptable, to enable the creation of new designs and new apparatuses that will lead to new solutions for specific applications. It is obvious that information is virtually everywhere and that screens and displays have to adopt a multitude of technologies and forms dedicated to targeted applications in public or private places. For this reason, bright optical fibre fabric displays have a significant role to play, particularly in the field of very large flexible displays.

Table 8.1 OFFD applications

Segment	Application type	Target population
Civilian	Leisure/business	Adolescents; adults; businessmen; people using wearable computers, E-mails, fashion clothes. . .
Public safety	Fire fighting/law enforcement	Firefighters, police
Car industry	External indicators, inside displays	Car makers, designers
House/buildings	Decoration, indication	Architects, decorators. . .

8.4 Acknowledgements

The authors would like to thank Dubar Warneton,[35] Cédric Brochier Soieries[36] and Audio Images[37] for their contribution to the development of the optical fibre fabric. They also would like to thank Michel Remy, Emeric Mourot and Gemma Ricci for their work and for their continued technical support on the hardware and software aspects of the project at FTR&D.

8.5 References

1. Halary C, 'L'ordinateur vestimentaire en devenir, Seconde peau au clone privé', 2000.
2. Bauer M, Kortuem G and Segall Z, 'Where are you pointing at? A study of remote collaboration in wearable videoconference system', *Proceedings of Third International Symposium on Wearable Computers*, San Francisco, USA, IEEE, 18–19 October 1999.
3. Smailagic A, Siewiorek D, Bass D, Iannucci B, Dahbura A, Eddleston S, Hanson B and Chang E, 'MoCCA: A mobile communication and computing architecture', *Proceedings of Third International Symposium on Wearable Computers*, San Francisco, USA, IEEE, 18–19 October 1999.
4. Vital Signs Monitor, Fitsens, http://www.fitsense.com/, FitSense Technology, 21 Boston Road, PO Box 730, Southborough, MA 01772.
5. Yang J, Yang W, Denecke M and Waibel A, 'Smart sight: A tourist assistant system', *Proceedings of Third International Symposium on Wearable Computers*, San Francisco, USA, IEEE, 18–19 October 1999.
6. Farringdon J, Moore A J, Tilbury N, Church J and Biemond P D, 'Wearable sensor badge and sensor jacket for context awarness', *Proceedings of Third International Symposium on Wearable Computers*, San Francisco, USA, IEEE, 18–19 October 1999.
7. Sangle-capteur de Polar, http://www.randburg.com/fi/polarele.html, Polar Electro Oy Professorintie 5, FIN-90440 Kempele, Finland.
8. Hong Z Tan and Pentland A, 'Tactual displays for wearable computing', *Proceedings of First International Symposium on Wearable Computers*, The Medialab Massachusetts Institute of Technology, Boston, USA, IEEE, 18–19 October 1997.
9. Thomas B, Grimmer K, Makovec D, Zucco J and Gunther B, 'Determination of placement of a body-attached mouse as a pointing input device for wearable computers', *Proceedings of Third International Symposium on Wearable Computers*, San Francisco, USA, IEEE, 18–19 October 1999.
10. Vardy A, Robinson J and Cheng L-T, 'The WristCam as input device', *Proceedings of Third International Symposium on Wearable Computers*, San Francisco, USA, IEEE, 18–19 October 1999.
11. Rischpater R, Project: the Spyglass: an interface for I-wear, *I-Wear Consortium Meeting*, Brussels, Belgium, Starlab, 6–7 June 2000, 30–35.
12. Cleveland G and McNinch L, 'Force XXI land warrior: implementing spoken commands for soldier wearable systems', *Proceedings of Third International Symposium on Wearable Computers*, IEEE, 18–19 October 1999.
13. Smailagic A, Siewiorek D, Martin R and Reilly D, 'CMU wearable computers for real-time speech translation', *Proceedings of Third International Symposium on*

Wearable Computers, San Francisco, USA, IEEE, 18–19 October 1999.

14. Kangchun Perng J, Fisher B, Hollar S and Pister K S J, 'Acceleration sensing glove', *Proceedings of Third International Symposium on Wearable Computers*, San Francisco, USA, IEEE, 18–19 October 1999.
15. Pratt V R, 'Thumbcode: A Device-independent Digital Sign Language', Stanford University Report, USA, July 1998, http://boole.stanford.edu/thumbcode/
16. Mills G, Slaten L, Broughton R, Malone K and Taylor D, 'Photoadaptive fibres for textile materials', *National Textile Centre Research Report* M98-A10, Volume 8, November 2000.
17. Gregory R V, Samuels R J and Hanks T, 'Chameleon fibres: dynamic color change from tunable molecular and oligomeric devices', *National Textile Centre Research Report* M98-C1, Volume 8, November 2000.
18. Gregory R V, Kimbrell W C and Kuhn H H, *Synth. Met.*, 1989, **28**(1&2), c823.
19. Gregory R, *Handbook of Conductive Polymers*, Second edn, Skotheim T R, Elsenbaumer R and Reynolds J R (eds), Portland, OR, Marcel Dekker, 1997.
20. Visson Israel Ltd, 1 Bezalel Street, Ramat Gan 52521, Israel, www.electronicsweekly.com/Article24123.htm
21. Kim Y K, Warner S, Lewis A and Kumar S, 'Nanocomposite fibres', *National Textile Centre Research Report* M00-D08, Volume 8, November 2000.
22. Du C W, Tao X M., Tam Y L and Choy C L, 'Fundamentals and applications of optical fibre Bragg grating sensors to textile composites', *J. Composite Struct.*, 1998, **42**(3), 217–230.
23. Tang L Q, Tao X M, Du W C and Choy C L, 'Reliability of fibre Bragg grating sensors in textile composites', *J. Composite Interfaces*, 1998, **5**(5), 421–435.
24. Du W C, Tao X M and Tam H Y, 'Fibre Bragg grating cavity sensor for simultaneous measurement of strain and temperature', *IEEE Photonics Technol. Lett.*, 1999, **11**(1), 105–107.
25. Tao X M, 'Integration of fibre optic sensors in smart textile composites – design and fabrication', *J. Text. Inst.*, 2000, **91**(Part 1, no. 3), 448–459.
26. Jackson D A, Ribeiro A B L, Reekie L, Archambault J L and Russell P St, 'Simultaneous interrogation of fibre optic grating sensors', *Proceedings OFS'9*, Florence, Italy, 1993.
27. Kersey A D, Davis M A, and Morey W W, 'Quasi-distributed Bragg-grating fibre-laser sensor', *Proceedings OFS'9*, Florence Italy, 1993, postdeadline paper PD-5.
28. Xu M G, Reekie L, Chow Y T and Dakin J P, 'Optical in-fibre grating high pressure sensor', *Electron. Lett.*, 1993, **29**(4), 398–399.
29. Jayaraman S, 'The first fully computerized clothing: A higher quality of life through technology', *Second International Avantex Symposium*, Frankfurt, Germany, 2002.
30. Deflin E and Koncar V, 'For communicating clothing: The flexible display of glass fibre fabrics is reality', *Second International Avantex Symposium*, Frankfurt, Germany, 2002.
31. Deflin E, Weill A, Koncar V and Vinchon H, 'Bright optical fiber fabric – a new flexible display', *The Sixth Asian Textile Conference*, 22–24 August 2001, Hong Kong, CD ROM Proceedings.
32. Veyet F and Koncar V, 'Innovation Textile: Les parapluies intègrent les écrans lumineux', *Rapport de Projet de Fin d'Etudes*, ENSAIT, Roubaix, France, June, 2002.
33. Bernasson A and Vergne H, *Optical Fiber with Multiple Point Lateral Illumination*, International Patent no. PCT/FR94/01475, 1998.

34. Deflin E, Weill A, Ricci G and Bonfiglio J, *Dispositif Lumineux Comprenant une Multiplicité de Fibres optiques à Segments Lumineux*, Brevet n°0102623 déposé en France par France Télécom le 27/02/01.
35. Vinchon H, Dubar Warneton, 136, rue Jules Guesde B.P.189, 59391 WATTRELOS CEDEX – FRANCE, http://www.dubar-warneton.com
36. Cedric B, Soieries 33, rue Romarin 69001 LYON, http://www.cedricbrochiersoieries.com
37. Bernasson A, Sarl Audio Images, Parc Ind. du Maréchat, 2 rue A. Einstein, 63200 RIOM – France, http://www.excel-ray.com