Chapter 13
The Commercialization of Smart Fabrics: Intelligent Textiles

George Kotrotsios and Jean Luprano

What is the relationship between hearing aids, corrective lenses, and smart textiles[1]? At first glance, none – but one thread, often invisible– is revealing in terms of the future of smart textiles. Hearing aids address a niche market, albeit a large niche – those persons (mostly elderly) suffering from what we still call today "impairment" – a hearing impairment. But is it not the same for corrective lenses? Can a young person or adolescent be considered an "impaired person"? Today, both corrective lenses and hearing aids improve human body functioning: corrective lenses are mainstream products that correct basic functions; and hearing aids are on the way to becoming mainstream products.

Extrapolating from this situation to smart textiles, one can see a similar, global trend developing. Today, smart textiles address niche markets, with relatively small market penetration to begin with, but tomorrow they will cover mainstream markets and help to improve the quality of life of continuously growing – and ageing – populations.

The underlying technology of smart textiles is multifaceted and integrating. It is best perceived as a platform that aggregates technological breakthroughs coming from fields as diverse as textile engineering, nanotechnology, microsystems, polymers and displays, communication engineering (including ad hoc protocols), multi-sensor data fusion, and many others. Each one of the aforementioned technologies brings unique features, while continuously added features reveal new applications and new benefits for the end-user, and therefore new business opportunities.

13.1 Analysis of the Markets: Today and Tomorrow

This analysis is an attempt to categorize the markets and applications for smart textiles today and to predict their evolution tomorrow. A secondary function of this

[1]We are going to use the terminology Smart Textiles to refer to Smart Fabrics and Intelligent Textiles; within this chapter, the understanding and the meaning of the terminology will be discussed.

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text is to give some background and clues to understand what the initial niche markets might be, and the advantages and drawbacks of each market segment. The principal objective is to understand which factors will accelerate (or decelerate) the transition toward the mainstream markets.

In this analysis, we address each one of the Smart Fabric, Interactive Textile (SFIT[2]) market sub-segments, as well as their nascent structures. An important objective of this article is to understand the value-generation processes and the interaction of the interests of the different parties. This understanding is the basis for identifying commonalities and levers that can contribute to the acceleration of the aforementioned transition. A secondary objective is to understand the potential of the "smartness" in terms of opportunities that never previously existed, and to try to foresee the directions in which such opportunities could evolve.

Such an endeavor is continuously evolving, and will continue to do so, because this integrating technology enables brand new services. The generation and evolution of such services depend on the overall technological and business climate. Let us take the example of telemedicine: will smart textiles be used for telemedicine services? Probably, but acceptance depends on non-technological factors, such as the international regulatory environment, liability of harmonization policies, and cross-country agreement on social security reimbursement.

13.1.1 What is a Smart Textile, as Seen from the Technology Perspective?

For simplicity, so far in this text we have used the terminology "smart textiles". The community which developed this domain usually applies the terminology Smart Fabrics and Interactive Textiles (SFIT). What is it? This question seems innocent enough. However, it is not so simple. We will explore this question further below.

The term "smart fabrics" relates to the behavior of the fibre, the yarn and the fabric itself: it has to do with the first three links of the value chain. Adding "smartness" at this level means modifying the reactivity of the material and even making some of this material part of a "programmed" machine, a microprocessor or a network of microprocessors. In contrast, the term "interactive textiles" usually denotes the capability of a system to integrate sensors, processors, and possibly also actuators, and to behave in a programmed way.

For instance, we can define as a "smart fabric" a device that changes color (using the properties of a nano-coating) in the presence of methane; this can be very interesting for security clothing in mining environments for example. We can qualify as an "interactive textile" a wearable device that concentrates information from multiple sensors, processes the signal using a microprocessor (or several microprocessors), and informs, for example, the emergency services of the health status of the wearer.

[2] www.csem.ch/sfit/html/background.html

Why is this distinction important? Because it underlines the increasing complexity of the already complex value chain, with the addition of new players that add "smartness" or "intelligence". The question is how these new players in the value chain can shape credible business models and which of them will endure and dominate. We will still use the terminology "smart textiles", understanding them as the overall domain of SFIT.

13.1.2 *What is a Smart Textile Seen from the User's Perspective?*

The definition of a smart textile, usually in terms of its function, varies considerably from source to source. Usually, the definition is determined by the function of the materials (e.g., carbon-nanotube-based materials), embedded intelligence, sensing capabilities, etc.

An important factor concerns what the function offers in terms of, e.g., sensing, thinking, etc., and consequently what added value is brought to the user.

The role of smart textiles as a technological support for the "augmented person" of the future is becoming today apparent as common denominator. In a very similar way that corrective lenses improve optical acuity, smart textiles can be seen as tools to improve functions such as:

- Perception of the environment and contextual awareness
- Monitoring of human health status
- Generation of energy (e.g., energy harvesting)
- Adding cognitive capabilities
- Interacting and interfacing
- Increasing human functioning

Functions performed by "wearables" were not anticipated two decades ago. It began with the pulse-monitoring chest belt (e.g., the one manufactured by Polar), which performs the online monitoring of human physiological parameters, and creates new roles and new market niches. The expectation is that the new functions of the smart textiles – this new shell of the human being – is going, by virtue of its functionalities, to contribute to the creation of new market segments for products and services. Therefore, we will attempt to map the market segments and related opportunities as they appear, while anticipating new – previously unimagined – market segments.

The global functions expected from a smart textile are outlined below and illustrated in Fig. 13.1.

13.1.2.1 Sensing

Sensing can be observed through multiple prisms:

- Sensing of the person
- Sensing of the environment

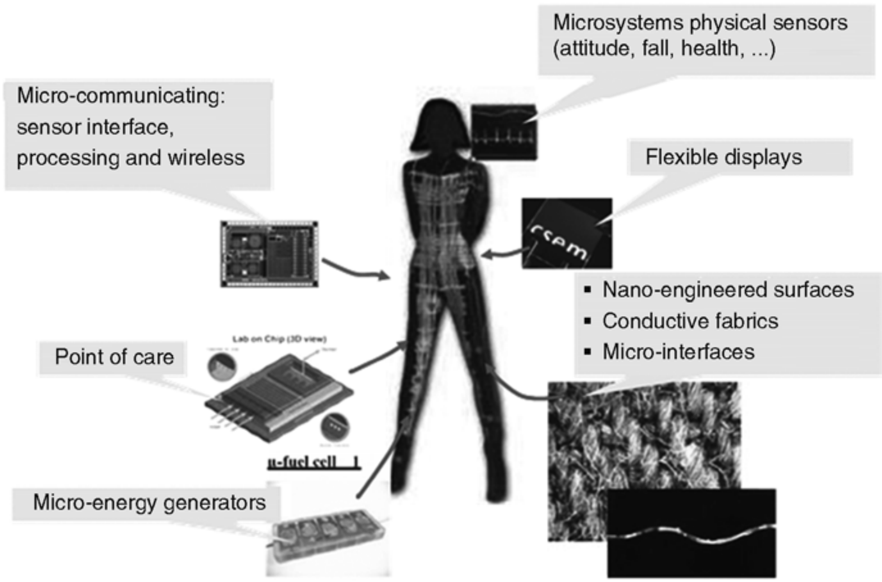

Fig. 13.1 Outline of main functions of wearable systems

- Sensing of the location of the person
- All or perhaps a subset of these

Sensing can also be categorized by types of measurements, and more particularly for the human body in monitoring of physiological parameters (body or skin temperature, posture, and gesture) and monitoring of biochemical parameters (e.g., perspiration).

13.1.2.2 Energy Harvesting

Energy harvesting can arise from the interior of the textile or from the exterior world. The latter mainly concerns solar, thermal, or mechanical energy, while the former concerns the mechanical and thermal energy produced by the human body.

13.1.2.3 Acting: Actuating

Two types of actuating mechanisms are present: physiological (acting on the human body, e.g., through piezoelectric actuators) or chemical, which can be either surface or bulk property changes, as triggered by external stimuli or even chemical delivery (e.g., controlled drug delivery).

13.1.2.4 Intelligence

Intelligence can be based on the use of conventional microprocessor(s) or in the longer term use of the textile itself as part of the microprocessor. These considerations imply the natural separation between distributed versus concentrated intelligence, whose implications are analyzed below.

13.1.2.5 Interface: Including Displaying

Concerning terminology interfaces, a number of parameters are implied. A first aspect is the interface which informs the user. It can be a display or an acoustic stimulus (e.g., voice) or a tactile stimulus (e.g., vibration) or another type of stimulus of our nervous system. Another consideration with regard to interfaces pertains to sensor-to-human, as well as sensor-to-environment, interfaces, which due to the stochastic behavior of humans require particular care. Finally, one might consider interfaces in terms of telecommunication links to remote locations (e.g., for medical telemonitoring of first responder in emergency situations).

As an ultimate vision, we can consider the continuous increase of performance of each of the aforementioned functions, up to a reconfigurable human augmentation type, according to the environment, function, moment, etc. Such reconfigurability could be performed either by dynamically modifying the textile, for instance by dynamically changing the parameters to be monitored: during one part of the day the measured parameters could be focused on medical diagnostics needs, while during another part of the day they could be focused on professional needs.

Coming back to the present, or even to the recent past, we see the ancestors of such futuristic systems in our everyday life: a pulse-monitoring chest belt and a pedometer are existing tools that allow us to monitor the human being and contribute to improving his own capabilities through conscious feedback (e.g., improving training conditions for athletes). The path toward increasingly complex smart textiles is nothing more than the increase in density of sensors or actuators and their ubiquitous and seamless integration on the immediate “human shell” (i.e., the smart textile) to augment the human potential.

Taking this view of the smart textile as an ultimate shell, the main roles of any shell in terms of protection, helping, healing, entertaining, or enjoying should be integrated and mapped into specific market segments. The functions of such a shell are continuously evolving, thus creating new markets and new opportunities for both products and services. In this logical first step, a higher diversity of the applications for smart textiles is going to emerge, as new opportunities will serve innovative applications currently not served or even existing today.

13.2 Common Backbone of Applications

In parallel, we have begun to observe a continuous convergence of application needs toward a common backbone: These form the basis of a future market consolidation and transition of smart textiles from a high-end product to a commodity. These areas of convergence are described below.

13.2.1 SFIT Configuration

13.2.1.1 Elementary Functions Without Embedded Intelligence (e.g., Reactive Color Change)

We understand by this category functions that operate without the use of microprocessor intelligence. To better describe this category, we can use the example of micelles, that open or close depending on the chemical environment, releasing pharmaceuticals into the body.

Another good example consists of nanostructured patches, embroidered on textiles, that, for example, can change periodicity (and therefore color of diffracted light) when absorbing human liquids (e.g., detection of wound healing).

13.2.1.2 Intelligence Embedded in the Textile

We understand by this configuration a complex function achieved by the process of sensing and interfacing of data devices that are using some kind of digital intelligence.

The most straightforward of digital intelligence systems are tiny microprocessors that can be equipped with communication features. Such devices can only be interfaced to the smart textiles either as unique devices that control the whole textile or as multiple devices that exchange information from multiple points on the same textile.

The newest configurations addressing intelligence are no longer embedded on conventional microprocessors, but rather on the textile itself. Integration can occur through the use of fibers that have semiconducting properties, and can therefore behave as elementary nodes of a large microprocessor.

Another aspect is the use of rapidly developing polymer electronics. Flexible polymers can be part of the smart textile itself as displays, but also as microprocessors.

13.2.1.3 Distributed Versus Localized

In terms of application approaches, one can see two large categories: distributed or localized (or obviously a combination of both). This is the architecture of the microprocessor(s) and the embedded intelligence itself. However, the essential

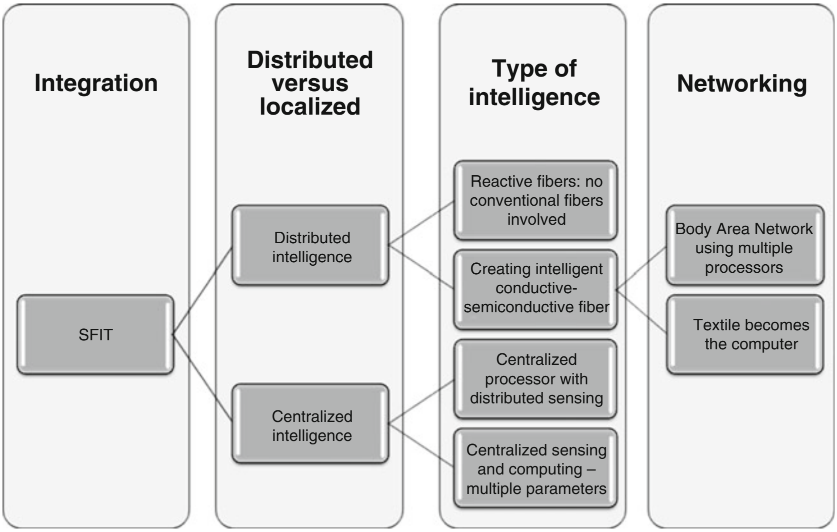

Fig. 13.2 Type of smart fabrics and intelligent textiles according to the type of sensing/actuating and processing

point is that microprocessor architecture should follow the needs of the application for sensing and actuating.

Distributed sensing means that almost each part of the textile is in itself a sensor. The example of the motion sensor Capri (Carpi and De Rossi 2005) is an excellent example. Natural Sensor redundancy is an important asset of such configurations, since with such high numbers of sensors, failure or sensor misplacement can be covered by signals coming from neighboring sensors.

The advantage of having localized "smart sensors" lies in the simultaneous measurement at the same location of several parameters; a combination of multiple measurands can lead to extremely useful conclusions. The European Space Agency's LTMS program (Krauss 2009) for the monitoring of astronauts in future manned missions has adopted precisely this approach.

We expect in the future a combination of these architectures, ultimately on the same textile, therefore offering the better of the two to the user.

These functions are outlined in Fig. 13.2 above.

13.3 Present Situation and Competitors in Terms of R&D and Commercialization

The market today is fragmented – this is often the nature of nascent markets. This fragmentation results in the presence of several small companies; in some cases, these small organizations emerge as spin-offs from much larger organizations.

The traditional value chains developed over centuries of textile development (Fig. 13.3) have been revolutionized:

In terms of intelligent fibers, one can identify a number of corporations. In the UK, Eleksen[3] is producing pressure-sensitive fibers and is therefore positioned on the left side of the value chain (Fig. 13.3), as a new player. Further left is the basic technology provider Paratech,[4] which has developed the Quantum Tunneling Component, which in everyday terms means electrical conductivity increases.

Eleksen is not alone in this domain. Companies such as Auxetix[5] are attempting to capture value through ground-breaking developments (in this particular case, auxetic fibers, i.e., fibers with negative expansion coefficient). These two examples do not fully represent the list of companies active in the left part. However, the citation of their positioning is intended only to illustrate the value capture mechanism in this part of the new value chain.

In the center of the value chain are companies that provide subsystems that can be integrated in the textile. Such subsystems can offer different integrated functions. Energy generation is the first, very important function, and solar energy capture is among the most efficient ways of capturing such energy. Konakra[6] in the US is positioned in this segment. Other companies such as Switzerland's Flexcell[7] are also making valuable contributions. Thermoelectric energy generation (i.e., the temperature difference between the human body and the exterior world) has been investigated for years with significant technical success by Infineon.

Another area of interest is the communication of information in a visual way: this is enabled by polymer displays. Numerous companies are active in this arena, aiming to penetrate the market of flexible displays. One of them applies such displays to wearable systems. Philips, with its Lumalive[8] textile integrating displays, has made a very interesting demonstration. This particular development is positioned in the middle of the value chain; that is, the integration of high-end components. However, one can easily imagine that such a large corporation can vertically integrate complete solutions.

Going to the right-hand part of the value chain in Fig. 13.3, we identify a number of subsystem integrators in or on textiles: typically, Ohmatex,[9] based in Denmark, Clothing+[10] of Finland and industrial R&D and smaller-scale production facility Smartex.[11] All these companies are targeting the integration of fibers and yarns in the fabric with a clear trend towards full systems.

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[3] www.eleksen.com

[4] www.peratech.com

[5] www.auxetix.com/science.htm

[6] www.konakra.com

[7] www.flexcell.com

[8] www.lumalive.com

[9] www.ohmatex.dk

[10] www.clothingplus.fi

[11] www.smartex.it

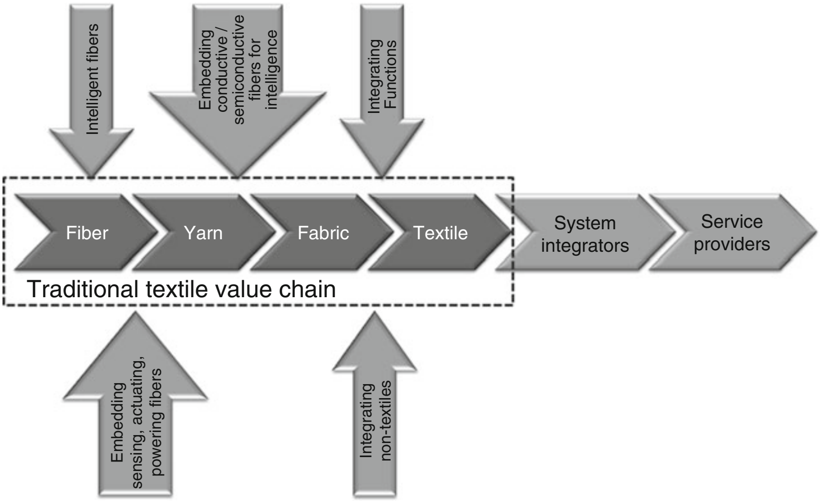

Fig. 13.3 Outline of value chain of textile and changes introduced by the advent of smart fabrics and intelligent textiles

Early phases of consolidation are starting to appear, including Textronics,[12] a spin-off of Invista, and targeting the exploitation of technologies from that company. Consolidation of the company within Adidas is a considerable step towards mass marketing.

Vivometrics,[13] one of the market's early movers, has made enormous efforts to create impetus for smart textiles in the market place. Vivometrics was among the first companies having addressed both products (Lifeshirt device) and services (Vivosoft), in particular services for data consolidation and reporting to business customers.

Apart from Vivometrics, one of the pioneering companies in this field is Sensatex,[14] which at the beginning of the decade produced the Smartshirt systems. Both Vivometrics and Sensatex were positioned closer to the final user – Vivometrics by providing elaborated signal analysis was also positioned as a service provider.

The UK-based company SmartLife[15] is also moving in the same direction, focusing on a dry sensor technology that improves reliability of the sensing system of physiological signals.

WearTech,[16] a company created in Valencia, Spain, is tackling the market of wellness. WearTech emerged from companies and research centers having participated in the European Commission's integrated project MyHeart.[17] This company is positioned closer to service provision.

[12] www.physicventures.com/textronics

[13] www.vivometrics.com

[14] www.sensatex.com

[15] www.smartlifetech.com

[16] www.weartech.es

[17] www.extra.research.philips.com/euprojects/myheart/

Sensecore[18] from Switzerland is initially targeting the markets of professional sport, in a vertically integrated manner, focusing its strategy on smart electrodes (as opposed to distributed sensing). A competing technology, albeit not in full-shirt configuration but rather in belt configuration, is commercially available from the US company Zephyr.[19] To complete the chain, companies such as the Swiss Athlosoft[20] use devices from, e.g., Zephyr and capture their own value through customer service.

It is interesting to note that in a number of cases some actors completely new to the traditional value chain are appearing. Furthermore, these actors compete in different parts of the value chain, producing a large diversity of product types.

The introduction of some major corporations indicates the first stages of market consolidation: however, taking into account the aforementioned structural market variability, it is expected that the market will be maintained fragmented for quite a long period, thus hindering fast growth.

13.4 Market Segmentation

Market segmentation in this rapidly changing environment is not simply an exercise in style; it is rather the foundation of understanding how the field is going to evolve and the key forces behind it.

Among different ways of segmenting the market, we propose to accept the splitting in:

- Medical
- Military
- Sport
  - Elite athletes and
  - High level amateurs
- Wellness
- Health
- Professional and protective
- Consumer and Fashion

13.4.1 Medical

Medical is a large market segment that can be subdivided into multiple ways. Since the objective here is to understand the value-creation mechanism, a logical way of segmenting the market is by using the criterion as the sources of revenue. One could be regular

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18 www.sense-core.com

19 www.nzherald.co.nz

20 www.athlosoft.com

medicine, involving professional devices, and the other could be self-healthcare devices, which can be purchased in pharmacies (such as blood-glucose meters).

In the case of SFIT, by "regular medicine" is meant the use of such smart textiles in disease prevention, monitoring, and rehabilitation processes, though while being under treatment by a medical doctor. Efforts to introduce such systems have been widely deployed in the past. In such cases, the objective was to use discrete measuring systems, such as ECG holders or belts. One of the most interesting cases was that of Philips Telemedical Services, deployed at the beginning of 2000 and targeting Denmark, Germany, Switzerland, and Italy. The model was initially based on the payment of the person and/or his family of a relatively small daily amount.

By self-healthcare is meant the use of SFIT by the individual, without medical prescription or follow-up, to monitor and improve her own health. In this case, there is certainly a good overlap with what we refer to below as the "wellness" market segment; however, the overlap is not complete and here we will attempt to address the medical aspect.

Medical CE and FDA approval will certainly be a delaying factor in terms of market penetration in this segment. This argument becomes even more pertinent if one considers that the majority of the smart textiles that are on the market today, or close to the market, suffer from poor interfaces between the textile and the wearer, due to the natural movement of the body. Reliability of the interface between the textile electrodes and the body requires general improvement.

The challenge is, however, certainly enormous. Control of the increasing costs, while maintaining comfort for the patient and ensuring security, will be a key market penetration factor. Rapidly changing demographics will moreover create excellent opportunities.

An interesting case that has not been previously considered in the literature is the integration of the elderly in society. This is not considered as a mainstream "medical" issue. However, lack of integration and increased isolation leads to risk of rapidly increasing psychological diseases of the elderly. Then we can see the average elderly individual as a person at risk, not only because of somatic diseases (e.g., cardiovascular, diabetic, or neurodegenerative diseases) but also for psychological conditions that can appear alone or in conjunction with neurodegenerative diseases. In this case, smart textiles can and will play an important role, not only in the monitoring of the physiological parameters and/or the physiological impact of psychological diseases (e.g., perspiration, tremor, lack of sleep, etc.) but also as tools to communicate and interact with society.

Infant monitoring, beyond avoiding sudden death, but also in optimizing monitoring of the vital functions, can open considerable new markets. In this field, the business models will in the near future follow two paths. The first one is of regular medicine, where the physician will, within an appropriate legal and financial framework, monitor the child. The second path is the one of the consumer market, where the family purchases such systems to monitor the infant's situation and to prevent sudden death. Respiration, skin and body temperature, as well as perspiration, are among the most important parameters to monitor.

The requirements for success are multiple, including:

- CE and/or FDA certification
- Introduction of an appropriate business model

Another extremely interesting development is the increasing appearance of diseases characterized by the degeneration of main functions. The need for artificial organs such as artificial pancreases, artificial livers, etc., will steeply increase over the following decades, in particular due to the ageing of the population and the shift of disease types from acute to chronic.

Obviously, a lot more than just smart textiles will be required for these treatments; however, the smart textiles, if developed to an acceptable level of reliability and quality, will be an important complement to implantable devices.

One of the additional exploitation paths in the market is the use by the pharmaceutical industry of wearable devices, for instance in clinical tests. This is just one example of its application in pharmaceuticals.

13.4.2 Wellness

Wellness is considered here as the market segment of individual consumers who are willing to use SFIT as tools to contribute to their own everyday well-being. This is a consumer market segment, where previous successes of predecessors of smart textiles have proven their feasibility. The example of the Polar belt is the most interesting. Its evolution and the cooperation with Textronics and Adidas (Textronics[21]) seem a very natural step forward where the probability of success seems high, due to the potential of each individual market.

Yet another case worthwhile to underline is the Nike pedometer system, associated with the Apple iPod; the most interesting aspect of this is that an internet community, through a dedicated website, succeeding in strengthening the market appeal of the concept.

In both cases, it appears that the business model can be feasible and successful. However, the parameters monitored (ECG – pulse in the case of Adidas, and distance and running rate in the case of Nike) can certainly be enriched and this will certainly accelerate market penetration.

In such configurations, and as opposed to the elite sport market segment, the ubiquitous communication feature is not a must. It may become that such ubiquitous measurement becomes a market need in the future, but for the time being the person caring about her wellness is more inclined to display and store data and possibly share data after exercise, but not necessary in real-time. Real-time display (or acoustic communication, through, for example, artificial voice communication) is an interesting tool.

[21] www.physicventures.com/textronics

Several start-ups are currently active here, one of which is the aforementioned very interesting case of WearTech, in Valencia,[22] which is a spin-off of the European Commission funded project MyHeart.[23]

An interesting feature of this business-to-consumer segment is the uniformity expected in terms of performance monitoring. The appeal of the online community is going to generate requirements for focusing on a defined set of monitoring parameters that all users will share. Today, such parameters are pulse (e.g., Polar, Suunto, Decathlon belts) or distance running (Nike pedometer). It is quite likely that the list will lengthen, but it is also likely that a common denominator of parameters, though limited in number, will remain.

For the time being, this segment does not require medical quality data. However, it is likely that the user level of requirements will increase during the coming years. Engineers will need to identify ways of providing this quality.

13.4.3 Military

The Military is one of the segments considered to be among the most demanding. It has been considered, and is still considered, to be a potential killer application. The reason is twofold:

1. In terms of protecting personnel, smart textiles can add value from multiple points of view: monitoring of physiological situations (before, during and after combat, optimization of training) is one of the most obvious applications. Obviously, this is valid for infantry, but also for pilots of aircraft and vehicles.
2. In terms of business potential, it is a large segment, but it is also a segment that can produce, uniform, large-scale orders.

The main weakness of this segment is that the penetration is time-demanding; this demands large commercial structures that have the resources to face the stringent needs and the long-time requirement; this can be incompatible with the structure of this nascent market, which is based on small companies.

13.4.4 Professional/Protective

These are large business-to-business markets, with a high degree of variability and enormous potential for evolution. Professional and protective market segments might seem at first glance unattractive – this is not actually the case. High replacement rates, in particular in specific markets (e.g., industry) can create interesting opportunities. In this case, smart textiles are expected to increase the productivity, performance, and

[22] www.weartech.es

[23] www.extra.research.philips.com/euprojects/myheart/

security of professionals. The difference in motivation for a purchase by a customer, between productivity and usefulness, is very important.

The nature of this segment is concerned with a high degree of quality and reliability in terms of measuring and interacting; no error can be tolerated when human life is at stake. However, taking into account the imperfect interfaces between the textiles and the human body, the factor of quality and reliability is expected to delay somewhat the introduction of smart textiles in this segment.

As far as security is concerned, one might consider a number of examples, for example mining or protective clothing for industry (e.g., metallurgic industry, electricity industry). In all of these examples, security is very important. Sensing devices, which for instance rapidly detect methane, can save hundreds of lives every year in mining. However, security is expected to come at minimal cost, since it does not bring additional revenues (i.e., no additional productivity).

In other market segments, where the smart textiles are expected to increase productivity, increased cost is more easily justified by purely economic rationale.

High renewal rates of professional clothing, together with potential increased productivity, could be ideal factors for fast market penetration. As far as we know, no such application has been identified up to now. In some ways, the aforementioned "elite athlete" segment can be considered as a segment with such characteristics, but with limited market volume.

It is expected that disruptive technology will quickly lead to applications, where the combined characteristics of increased productivity, high renewal rate, and business-to-business configuration will contribute to rapid market breakthroughs.

13.4.5 Sport

Within sport, we define here two subsegments: the professional market subsegment and the high-end amateur sport sub-segment.

Both subsegments of this larger sport market segment represent a natural extension of the wellness market (or *vice versa*, wellness can be considered as the natural extension of the sport market segment). Despite this natural continuity, the market segment structures are completely different: elite athletes have their own medical teams to follow them up; individual in wellness centers are monitoring themselves; the first segment is business-to-business the second business-to-consumer.

For professional sports, whether this has to do with individual sports or team sports, monitoring is today performed by professional medical teams that continuously monitor and optimize every single aspect of performance. This market is ready to upgrade the current tools toward more seamless devices, integrated in the textile, on condition that they provide quality medical data.

Each sport has its specific needs in terms of training and competition. Due to this specialization, this is a market that requires a high degree of flexibility and customization that is not adapted to mass production.

A deep medical understanding of sport medicine is required within those companies that commercialize smart textiles, to intelligently adapt to the needs of the users. Specific technical features are particularly important. Real-time communication and processing is of major importance, for training and in several cases, depending on the rules, for the activity itself.

Due to the limited number of top-level athletes, this market is by nature restricted. No single sport can sustain adequate business levels of companies working in this sector. Even the possibility of building a company focusing on elite sport teams or individuals for several sports is questionable, though not impossible. This possibility exists due to the increasing use of scientific/medical optimization through monitoring of the athletes' performance. Obviously, this subsegment is considered to obey the rules of a business-to-business relation, since customers are not the individuals but the teams, albeit with a limited number of individuals within each team.

For the subsegment of high-end amateur athletes, the situation is completely different. Here, the individuals who are potential users are usually extremely well-informed people, who manage their own performance.

The market itself is very different from the one comprising elite athletes. Here, the equipment is financed by the individuals themselves; the degree of price-sensitivity increases, however, due to the passion of such individuals for sport, and price therefore remains less important than performance and quality criteria.

Obviously, here we are moving toward a business-to-consumer market, and product standardization is important in reducing production costs. Again, the differentiation of needs of different sports requires a high degree of flexibility and customization. This is, however, in contradiction with mass production. Embedding flexibility and customization within the individual smart textile is the main challenge of this market.

13.4.6 Consumer and Fashion Segments

Consumer and fashion is the ultimate market segment. It will eventually flourish when manufacturers have gone through the learning curve, and when costs are reasonable, enabling competitive, and adequate consumer and fashion pricing.

Smart textiles, at first glance, are expected to play only a marginal role in high-end fashion; instead, they are expected to be more and more an integral part of mid-range garments. Fun and image are expected to be the key marketing drivers.

In terms of market type, business-to-business markets and business-to-consumer have fundamentally different characteristics with regard to market approach and penetration. An initial categorization is outlined in Fig. 13.4 below.

An outline of the relative importance of the factors presented here is presented in Table 13.1, below.

Market penetration, in particular for high technology markets such as the smart fabrics and intelligent textiles segments, starts from high added-value and high-margin market segments. Over time, these markets are moving toward high-volume, lower-margin products. Among the indicators of such transitions is the

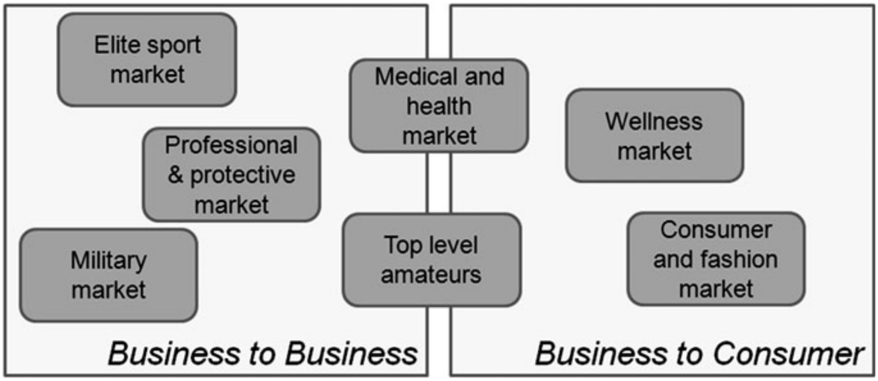

Fig. 13.4 Market segments and their character in terms of approach

Table 13.1 Main characteristics of the market segments

Market segment	Main characteristics
Sport (elite and high-end amateurs)	Needs applications with high visibility and high innovation level
	Small market volume
	Increasing demand from sport teams for optimization of performance
	Use of external tools, such as cameras, for monitoring of important (but not all) parameters
Wellness	Clearly proven – indicated for smart textile wellness
	Only a small part of potential functionalities
	Several competitors can establish themselves using existing tools
Professional and protective	High renewal rate
	Security is a "must" that does not justify cost increase
	Cases where smart textiles increase productivity and not only security are not yet clearly identified
	High cost inhibits market entrance
Health and medical	SFIT might be a factor in limiting sharp increases in health costs
	Multiple markets
	Requires long homologation periods
	Ageing society may in medium-term require tools to medically monitor and integrate individuals
	Newly conceived services based on new features
	e-Health, which uses such tools, is expected to get increased importance over the next years
	Legal, reimbursement and regulatory situation not resolved
Military	Big homogeneous market
	Market difficult to access
	Increased demand in western countries for soldier security
	Financial limitations
	Competing technologies
Consumer and fashion	Image of fun and modern
	Unpredictability of consumer markets
	Customer goods can only be low cost and very attractive
	Fragmented market

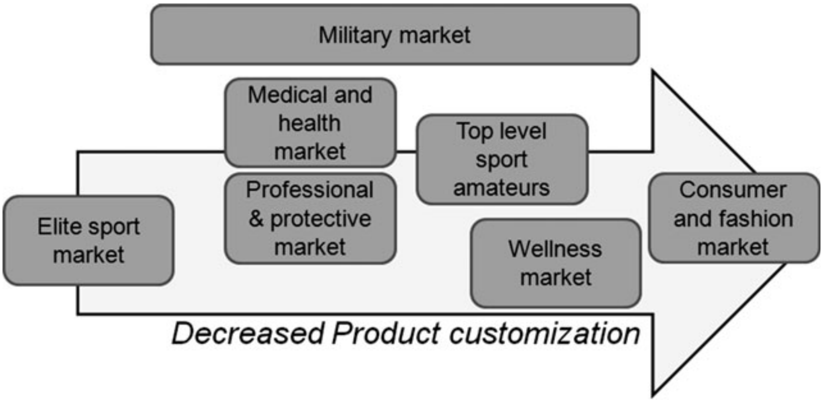

Fig. 13.5 Degree of customization as a function of market segment. This viewgraph is only a high level picture that due to the "smartness" of textiles can be rapidly modified

customization degree in each market segment. However, due to the "smartness" of the textile the customization can be higher at every level, as we attempt to illustrate in Fig. 13.5.

13.5 Market Volumes

To define a market volume, one needs to initially define the market perimeter, taking into account the numerous players and their revenue capture.

Several recent and less recent analyses can be cited. IntertechPira (2009) made a prediction of a $642 million market for 2008, with an expected growth of 28%. Venture Development Corporation (VTC), British Chamber of Commerce (BCC[24]), or Reportlinker[25] announce double figure growth as well as worldwide market volume forecasts of the order of the one billion US dollars. Last but not least, one other forecast of Frost and Sullivan (2009) mentions a growth rate of 76% for the SFIT market (SFIT[26]).

Market volume forecast can vary a lot; the main message from market and analysts is that a strong growth is expected, in a market which is going to be in the order of billion US dollars worldwide.

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[24] info.hktdc.com/imn/06120501/clothing219.htm

[25] www.reportlinker.com/p096832/Global-Markets-for-Smart-Fabrics-and-Interactive-Textiles-2008-edition.html

[26] www.csem.ch/sfit/html/background.html

13.6 Conclusions

If one can draw a conclusion, it is that the world market is significant, but still relatively small in terms of overall capitalization, and taking into account market fragmentation, it means that survival is difficult.

A second conclusion is that forecasts seem to lack coherence. This is explained by the definition of the market. Including services or not, and addressing systems or sub-components, can alter the perception of market volume and growth rate considerably.

In our understanding, the market for smart textiles (or more correctly expressed SFIT) is a significant albeit relatively small segment. We anticipate a rapid growth over the years to follow. We expect to see significant growth rates that will in the future establish SFIT as a main market, once a strong penetration is achieved in specific market segments.

As any product with high technology content penetrates first in specific niches, the additional presence of an adequate business model, including services, accelerates market penetration. Features that seem important are: (1) the potential of high renewal rates; (2) clear increases in productivity and/or performance; (3), business-to-business environment, and finally (4) existing or upcoming services.

The market is fragmented, and this situation will be maintained until a killer application leads to fast market growth. Some signs of consolidation are starting to appear.

Traditional value chains are getting more complex. The revenue-generation mechanism changes as new players enter this nascent arena. The continuous increase in technological features will continuously modify these mechanisms and is expected to create business opportunities requiring a high degree of flexibility and customization from industry.

References

Carpi F, De Rossi D (2005) Electroactive polymer-based devices for e-textiles in biomedicine. IEEE Trans Inf Technol Biomed 9(3):295–318

Frost and Sullivan (2009) Technical insights' high-tech materials alert. Frost and Sullivan

IntertechPira (2009) www.innovationintextiles.com/articles/Smart015.php. Accessed on 6 oct 2010

Krauss J (2009) LTMS: smart and wearable life sign monitoring. International Congress on Wearable Technologies, Münich