The Commercialization of Smart Fabrics: Intelligent Textiles

UNIT II

INTRO

- What is the relationship between hearing aids, corrective lenses, and smart textiles1 ?
- 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), multisensor 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.

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.
- Smart Fabric, Interactive Textile (SFIT2) market sub-segments, as well as their nascent structure

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?
- 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.

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 o**f, 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

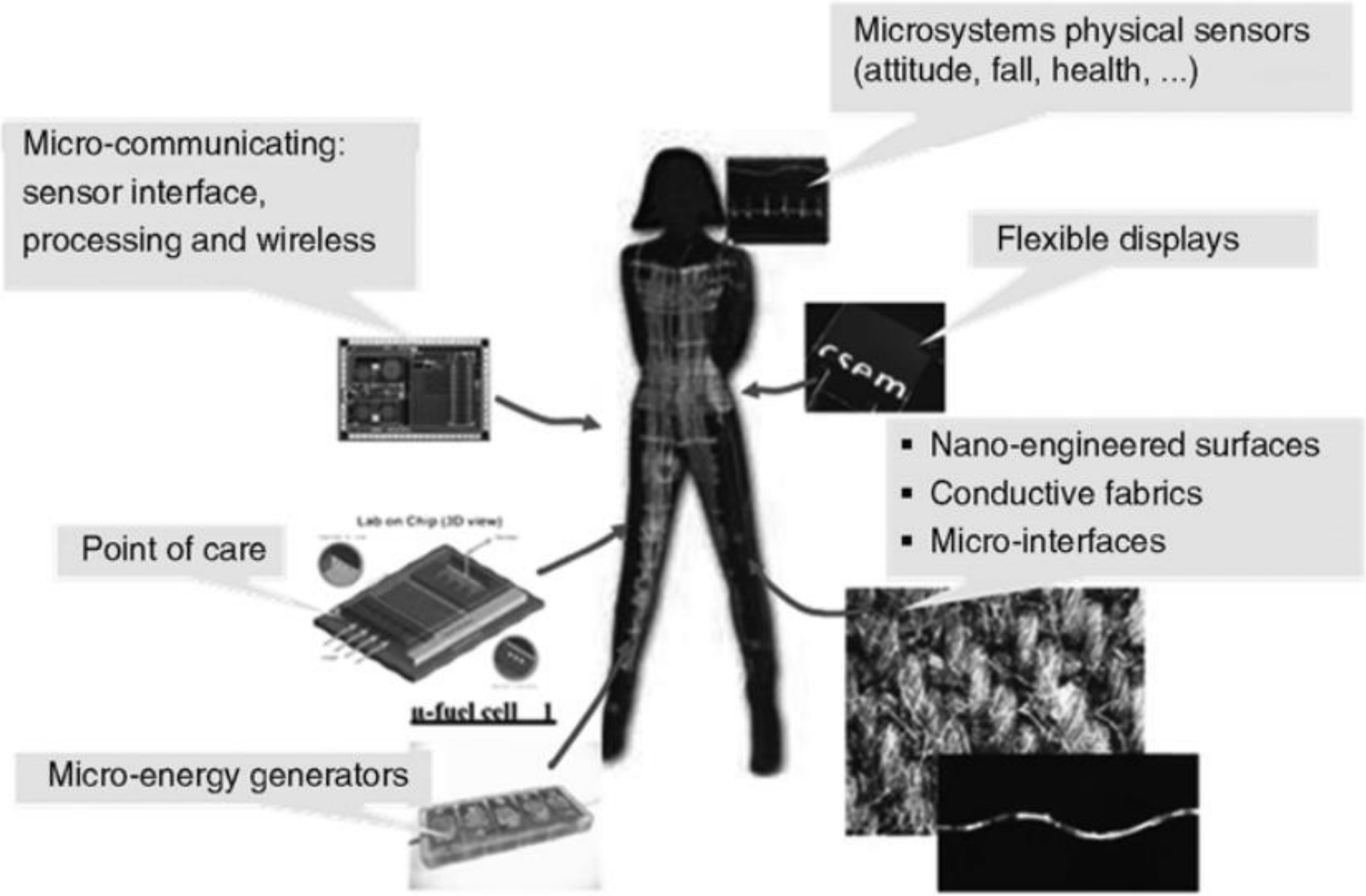

Fig. 13.1 Outline of main functions of wearable systems

Functions of wearable system

- 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: l Sensing of the person l Sensing of the environment
- Sensing of the location of the person l 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).

Functions of wearable system

- 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 surfaceor 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.

Functions of wearable system

- 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).

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

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

- Intelligence Embedded in the Textile

- Distributed Versus Localized

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 micro-processor 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 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.

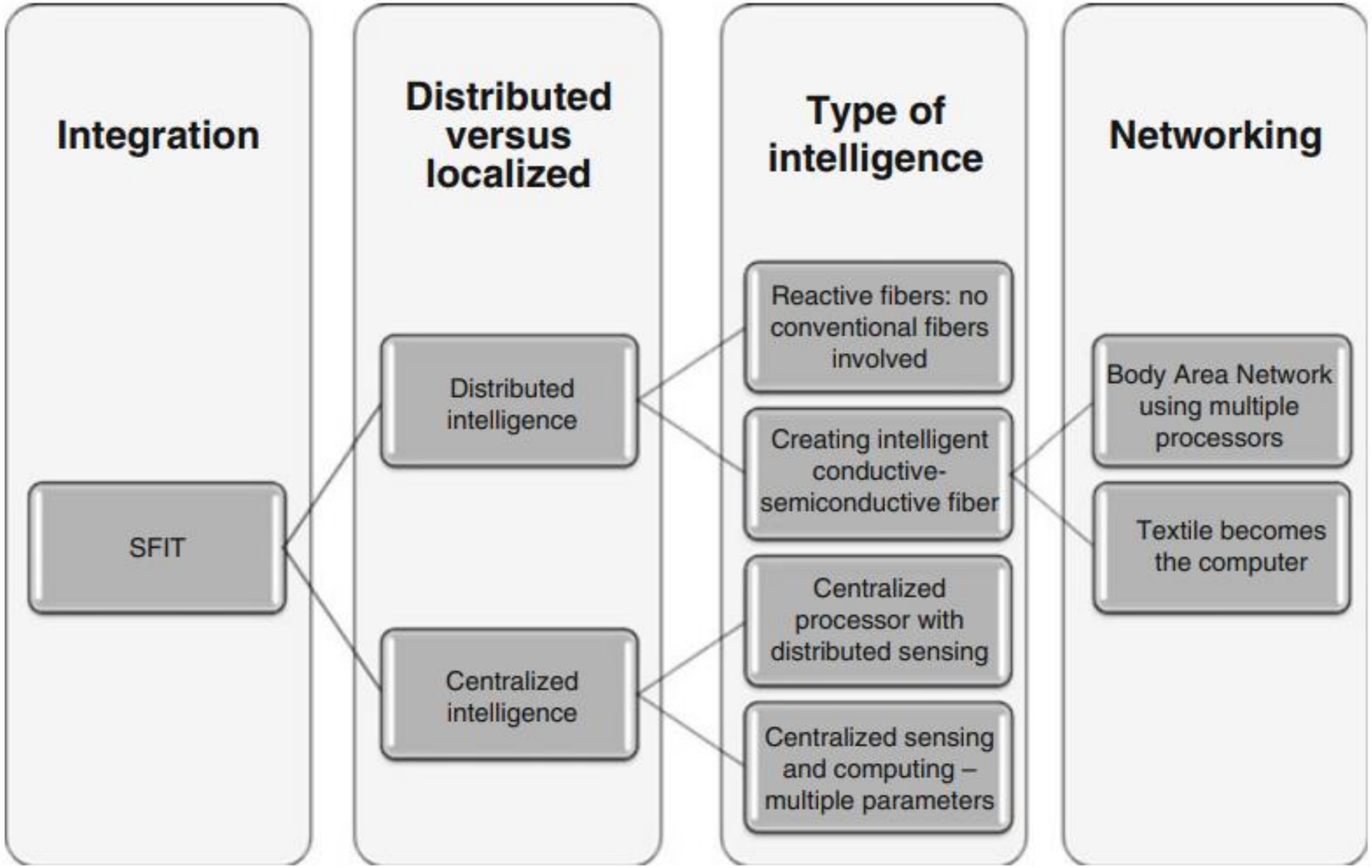

Fig. 13.2 Type of smart fabrics and intelligent textiles according to the type of sensing/actuating and processing

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, Eleksen3 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.

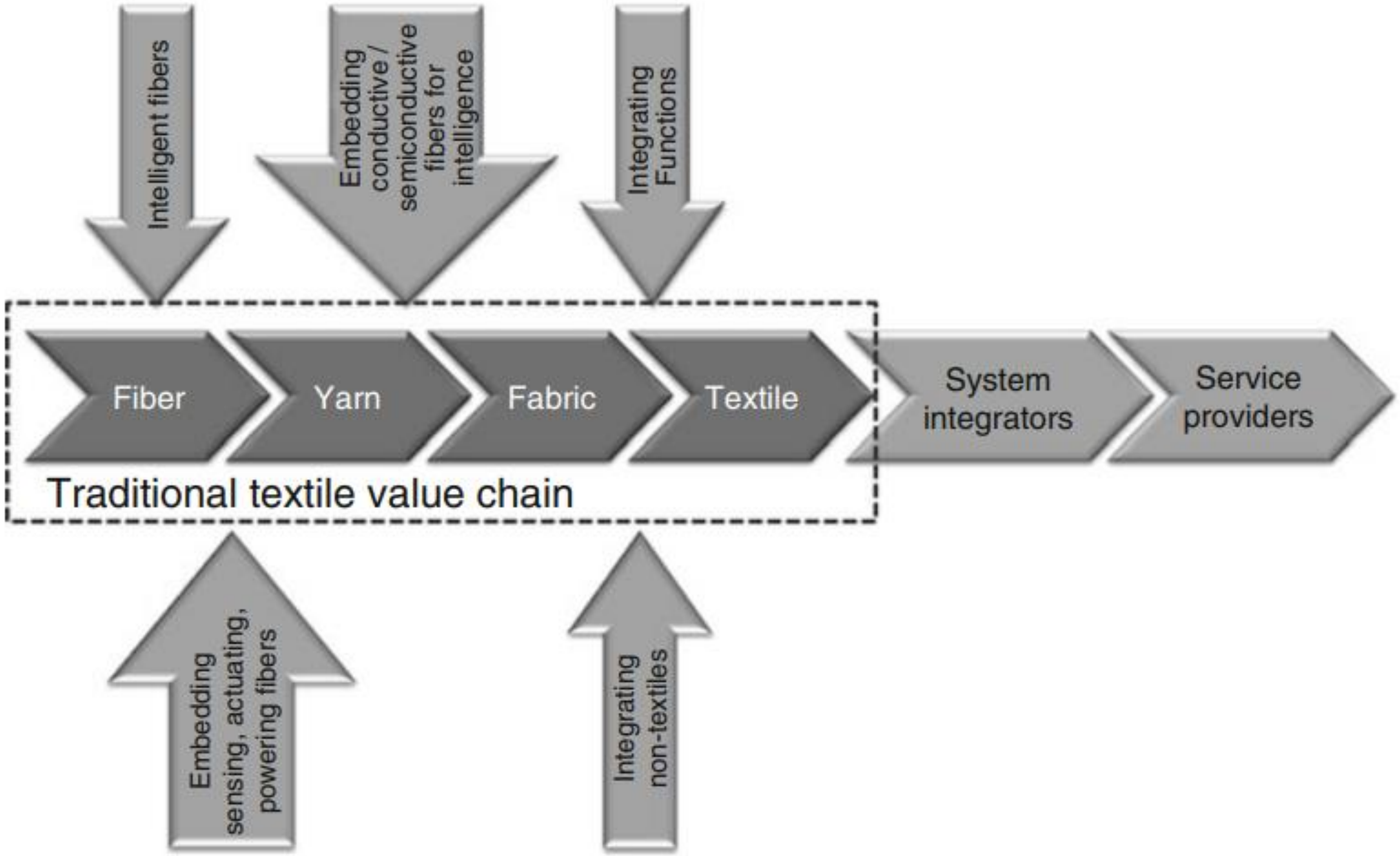

Fig. 13.3 Outline of value chain of textile and changes introduced by the advent of smart fabrics and intelligent textiles

- 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. Konakra6 in the US is positioned in this segment. Other companies such as Switzerland's Flexcell7 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.

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

13.4.3 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.

13.4.6 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.

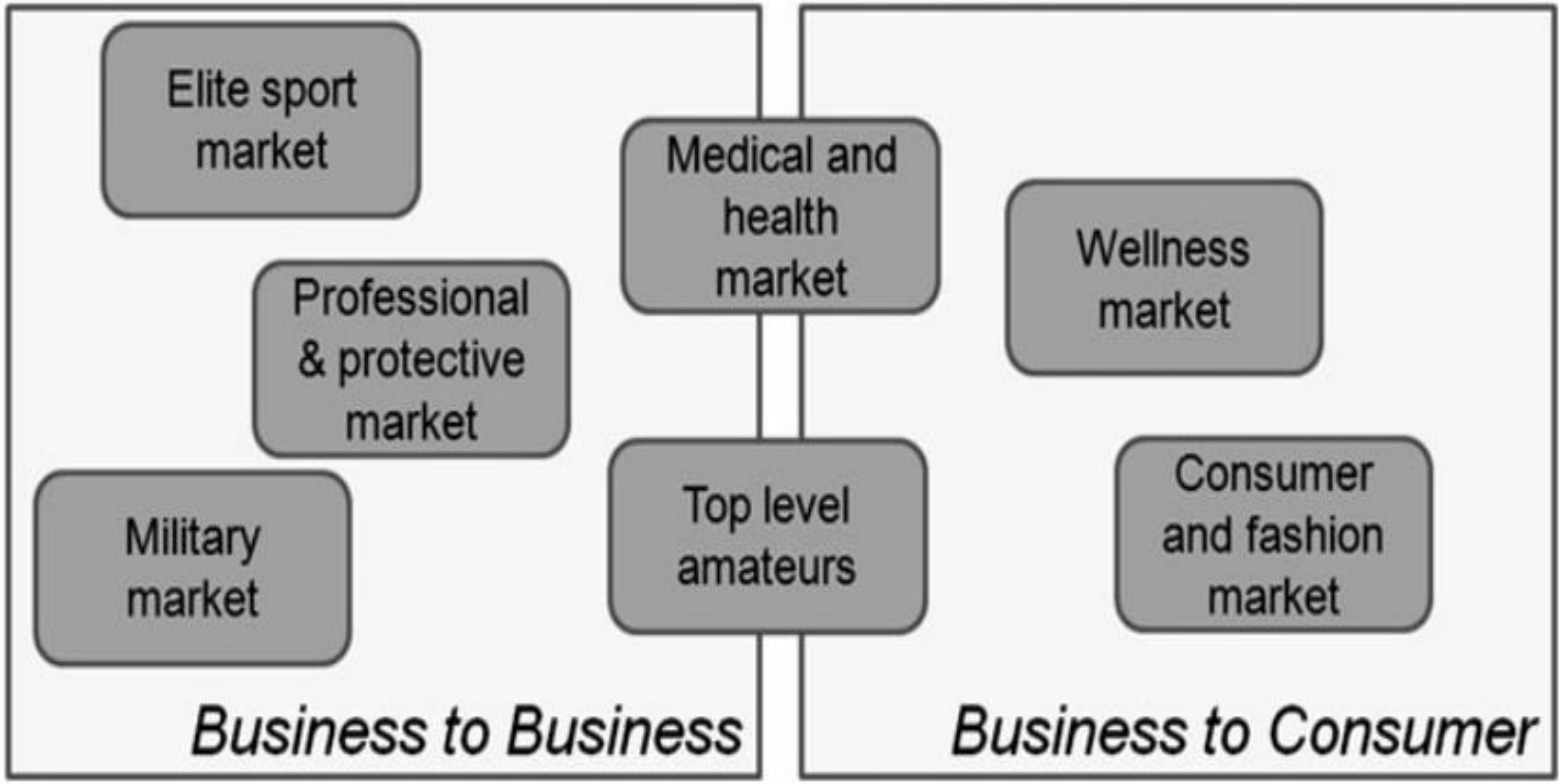

Fig. 13.4 Market segments and their character in terms of approach

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

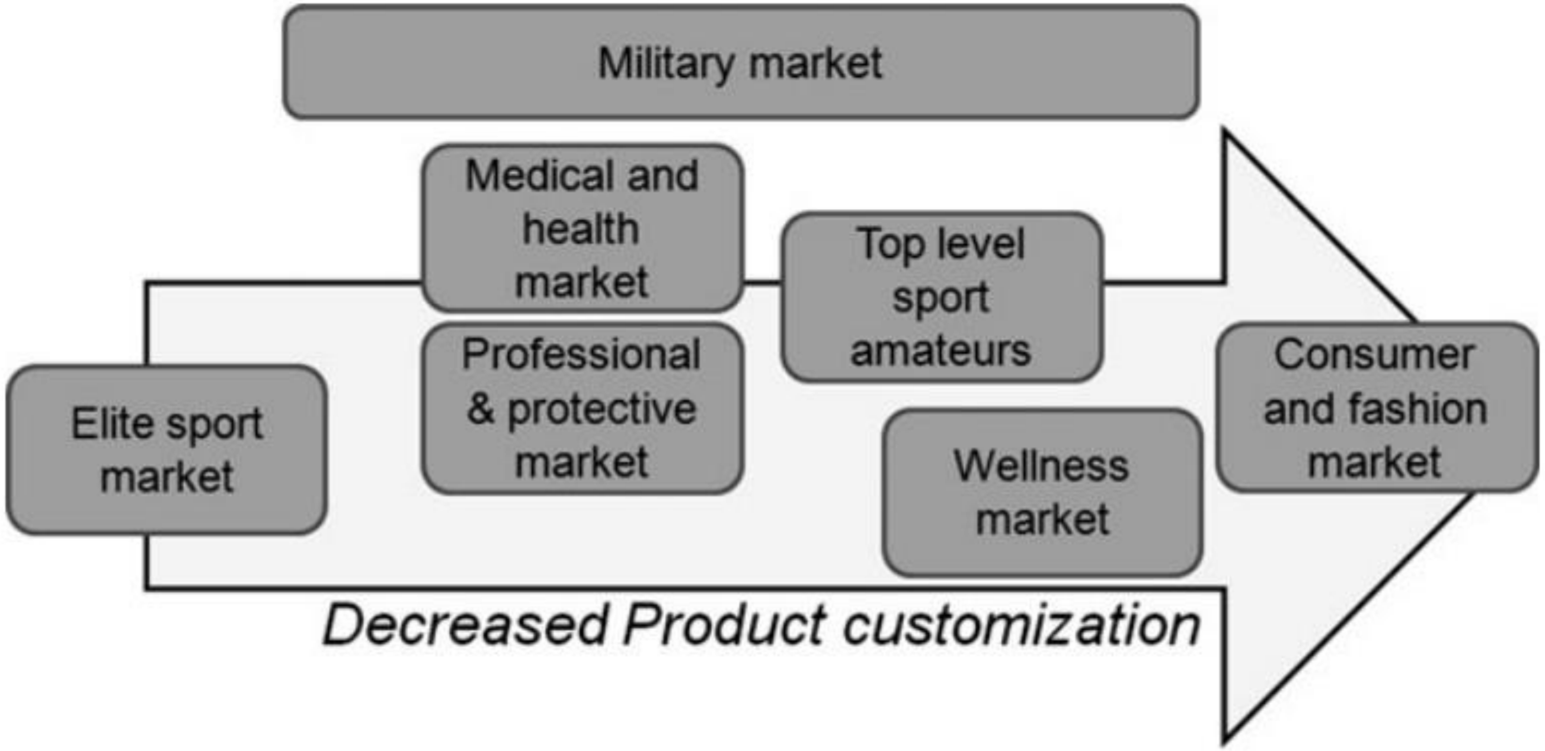

Fig. 13.5 Degree of customization as a function of market segment. This viewgraph is only a high level picture that due to the "smartness" of textiles can be rapidly modified

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.