Faculdade de Engenharia da Universidade do Porto

Patents in the Wearable Medical Devices Industry

Clara Maria Mansilha Nogueira da Cunha

Integrated Masters in Bioengineering
Major in Biomedical Engineering

Supervisor: Prof. Catarina Maia

July 2016

ABSTRACT

The use of wearable technologies in the medical field has several advantages to both the patient and the system itself. It allows constant monitoring, providing insightful data about patient's health, which can help the physician make a more accurate diagnosis. Moreover, it can potentially reduce healthcare costs that have been constantly increasing due to population ageing and, consequently, the increase of chronic diseases prevalence.

Despite the advantages, the overall market for wearable technologies is considered to be in a critical point since there is no adoption by early majorities. There are several challenges that need to be overcome and are especially related to data management and the comfort of using such devices.

In order to succeed, the industry needs to cross the chasm in which it stands. The study of the innovation profile of this industry can help understand its current status and if there is a technological opportunity underexploited. These studies can be performed by using a patent portfolio and analysing it in order to obtain information about innovation trends in a given sector. In this study, a new technology forecasting technique is presented. It is proposed that the combined analysis of patent pools and product portfolios can produce insights about innovation, potentially uncovering patent vacuums associated with product features. As an illustration, the current patent landscape in the wearable medical devices is investigated, particularly for wearable electrocardiography (ECG) devices. Through this combined analysis, we shed light into the intellectual property strategy in the wearable devices industry. The innovation dynamics is also addressed and future avenues for product evolution are pointed out.

ACKNOWLEDGEMENTS

First of all, I would like to thank Prof. Catarina Maia for the support and guidance that allowed me to finish this work. Without her, I wouldn't be able to learn so much about a topic that I knew so little, in this short period of time.

Secondly, I would like to thank all experts involved in this study. Their willingness to help me was crucial and highly appreciated.

I would like to thank my family, especially my mother. To see what you have achieved gave me strengths to overcome every single obstacle that I faced.

And finally, to my friends, thank you for being there for me, thank you for all the memories. You made these five years unforgettable.

LIST OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABBREVIATIONS

CAGR	Compound Annual Growth Rate
CPC	Cooperative Patent Classification
ECG	Electrocardiography
EEG	Electroencephalography
EMG	Electromyography
EPO	European Patent Office
ICO	In Computer Only
IPC	International Patent Classification
JPO	Japanese Patent Office
OECD	Organisation for Economic Co-Operation and Development
PTO	Patent and Trademark Office
TRIPS	Trade Related Aspects of Intellectual Property
USPC	United States Patent Classification
USPTO	United States Patent and Trademark Office
WD(s)	Wearable Device(s)
WIPO	World Intellectual Property Organization
WMD(s)	Wearable Medical Device(s)

1. INTRODUCTION

1.1 MOTIVATION

Wearable devices (WDs) have many different fields of application such as healthcare, security, fashion, etc. Nowadays, one of the major reasons that leads customers to buy such devices is related to their use both in sports performance (for measuring stamina, for example) and fitness (for counting steps, measuring caloric expenditure, etc.).

The use of wearable devices in the medical context has benefits not only for the patient but also for the healthcare system. In one hand, wearable medical devices (WMDs) are related with preventive medicine, a key point in reducing healthcare expenses [1], [2], on the other, they allow continuous patient monitoring, thus helping in the diagnosis and prescription of a personalized treatment for each patient [2]. An illustration of the use of WMDs is the monitoring of the cardiovascular system through ECG (electrocardiography) technology [3], [4]. The impact of cardiovascular diseases is increasing both in terms of mortality and morbidity, especially in developed countries. Consequently, there is a need for continuous monitoring systems that allow patients and physicians to evaluate the performance of the cardiovascular system [3]. Nevertheless, wearable devices, including the ones using ECG technology, face many different challenges that have delayed their adoption by the majority of the population. As a result, the overall market for these devices is considered to be at a critical point since it is in a chasm – there is a disconnection in adoption between early adopters and early majorities. This lack of adoption is caused by an extreme diversity of WDs, which is a result of a quick technological growth, causing confusion among customers, affecting their buying decision [5].

Therefore, in order to understand the technological dynamics of this sector, the need for analyzing innovation in the wearable medical devices industry becomes evident. Furthermore, such analysis may inform about product design choices, new business model adoption and development roadmaps, which can, in turn, promote product adoption [6].

Innovation analysis can be done resorting to multiple sources of data including, among others, surveys, sales data or scientific publications [7]. Patents have also been used as data source for this analysis, due to their widespread availability and the technical information they contain [8]. Moreover, it is worth noting that, according to Grupp and Schmoch, ”Private or corporate research generally produces patents rather than academic publications” [9]. Patent analysis has been used in several studies that resulted in insightful information about the investigated field. By designing a landscape of patents in the industry of wearable medical devices, it should be possible to identify underexplored technology opportunities, competitors and innovation trends. This information can potentially help investors and analysts to cross the chasm that exists in this industry.

In this work, our focus towards the analysis of innovation in WMDs will be relying on patent analysis and product characteristics analysis. Patent analysis can provide answers to many different questions allowing to understand which companies are present in the industry, what are the countries where innovation in the sector is being performed, what is the potential of R&D, etc. [10]. Thereby, different aspects of the dynamics of the innovation process can be mapped, such as co-operation in research, technology diffusion across countries or industries alongside with studies of the competitive process [11]. However, nowadays, the methods for patent analysis (e.g. text mining techniques) rely mostly on conjoint analysis of patent pools and patent pool visualization methods, overlooking what is already in the market (e.g. [5], [12]). To address this problem, we propose a new method for analysing patents consisting on crossing patent claims and related product features in order to understand the commercialization dynamics in the wearable technology market, focusing on ECG technology.

1.2 Goals and Methodologies

The main purpose of this work is to obtain information about the innovation profile of WMDs industry through the use of a new proposed method of patent analysis. Particularly, our main research goal is to understand whether this industry uses patents and if they are promoting or hindering innovation. A secondary objective to this work is to understand how the patents in this industry are related to certain product features, eventually uncovering technical areas that still have patenting space. As a surrogate for the wearable medical devices industry, we will use the ECG wearables.

The present work is organized in eight different chapters. First, we focus on the evolution of wearable technologies giving a special attention to wearable medical devices, ECG technology and the social and economic impact that result from their use. Then, different methods for innovation studies will be presented, highlighting the advantages and disadvantages of using patent analysis. We continue by presenting the proposed method, and then we will present the results, showing the insights that the new proposed method can produce, illustrated by its application to the wearable devices industry. The next chapter focuses its attention on the interpretation of the obtained results, alongside with a critical analysis of the proposed method. We finished by drawing conclusions related to the innovation in the WMDs industry.

2. WEARABLE TECHNOLOGY

Wearable technology is not a novelty. Its use can vary from the medical industry to military, security or even fashion. In this chapter, an exhaustive analysis of the background of wearable devices is made with a particular focus on wearable medical devices. A market characterization is also performed, further analyzing both social and economic impacts of the adoption of these technologies for healthcare.

2.1 WEARABLE TECHNOLOGIES

Wearable technology isn't a new concept or phenomenon [13]. Historically, the use of wearable technologies dates back to the use of watches which, with the new digital era, evolved. New features were added, like calculators, timers or even calendars, allowing the fabrication of small and portable multi-function devices [14]. As soon as internet expanded alongside with new discoveries in the field of engineering, these devices acquired new characteristics, being also able to recognize users' state and perceive the environment surrounding them without interfering with their daily activities [15]. Therefore, and according to their role, they can perform different basic functions like sense, process, store, transmit or apply signals. Figure 2.1 is a schematic representation of this type of functions, between the device and the location where data is being treated (remote location) [16].

Nowadays, wearable technologies range from wristbands to smart watches or clothes and have the capability of being connected all the time [14]. As shown in figure 2.2, there are plenty of activities that benefit from the use of wearables. The different sectors that benefit from these technologies are related to security, communication, sport/fitness, lifestyle computing, health among others. In a review of wearable technologies, Park and colleagues [16] give also some examples of the use of wearable technologies. They state that WDs can be used to guarantee first responders safety and to monitor both their physical conditions and the environment surrounding them. WDs can also help in elderly care, by monitoring their health and well-being, providing information to other people, for example, to their physician or relatives. Many different examples are given, but they all have in common the value that can be delivered not only to users but also to the people accessing the recorded data [16].

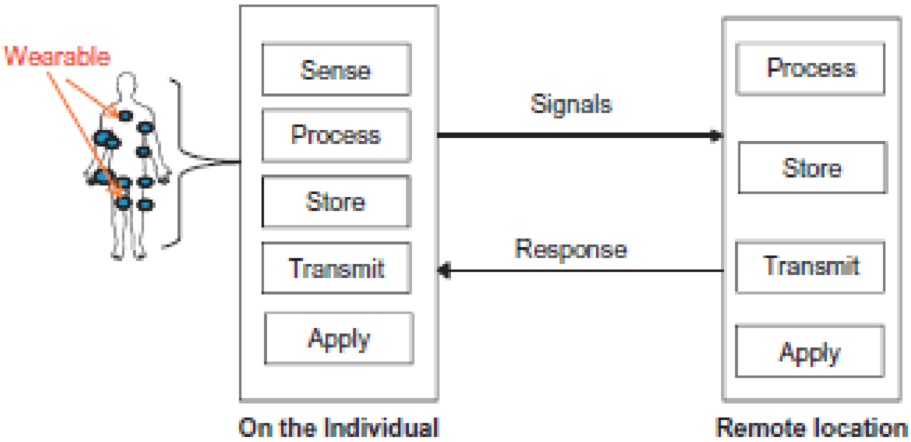


Figure 2-1 - Different Interactions between the individual and the Wearable Technology. Available on [16]

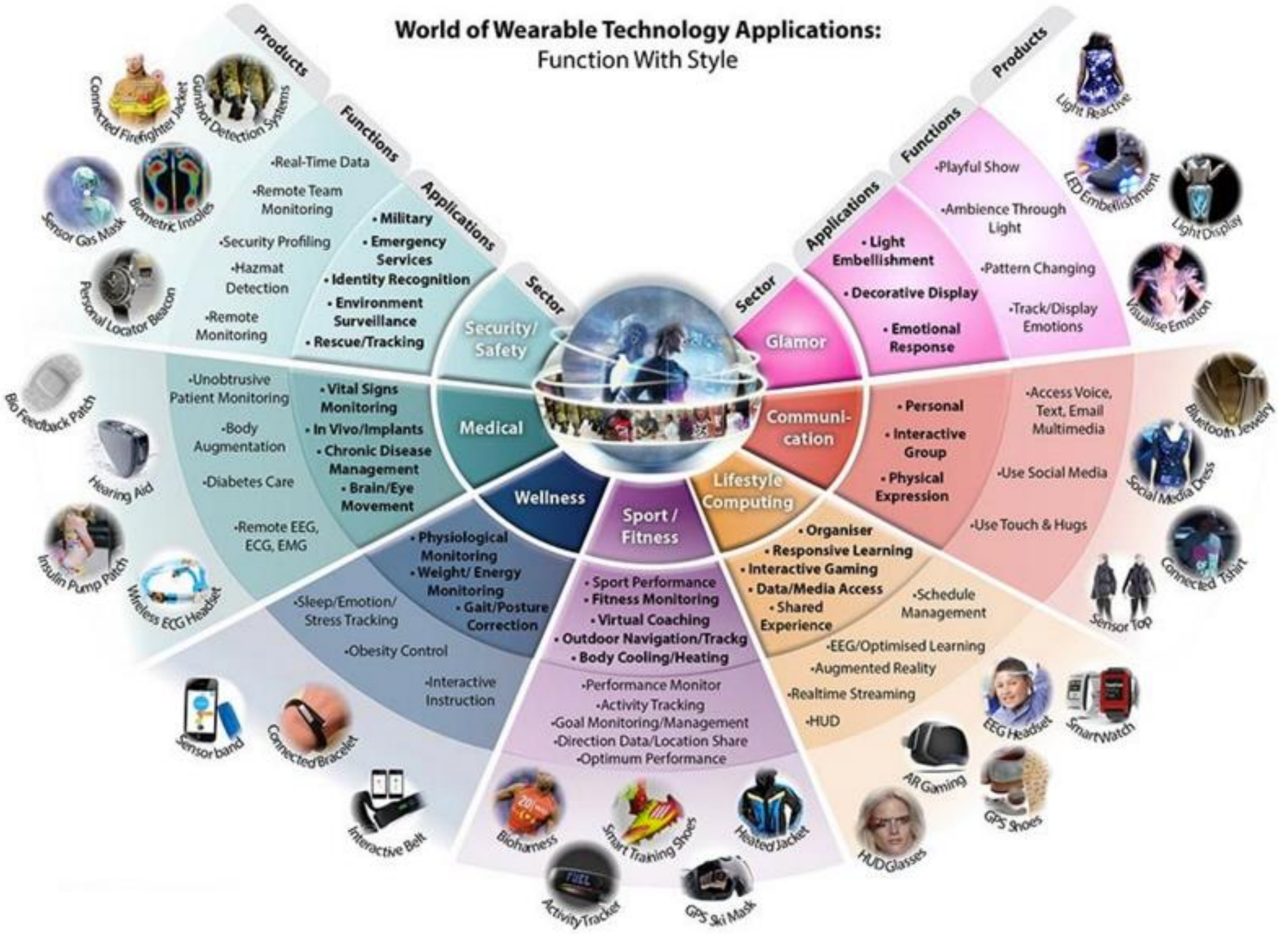


Figure 2-2 - Different uses of wearable technologies. Available on [50], [2]

Thus, wearable technologies can be considered as external devices that can be, in some way, integrated into users' outfit or can be worn as an accessory [17]. In 1998, a three category definition, as stated in table 2.1, was also suggested, considering the existing products and prototypes [18].

Table 2-1 - Category Definition of Wearable Technology. Adapted from [2] and [6].

Category	**Definition**
Wearable Computers	Computing device that is able to be carried on the body, having the user interface ready for use. It allows input and output through the use of qwerty-keypads, special keying devices, joysticks and graphic interfaces, like LCD-displays. Feedback is also possible with sound or vibration. It can be reprogrammed or reconfigured for different tasks, including adding or removing hardware.
Wearable Electronics	Unlike wearable computers, wearable electronics are simpler and set with specific tasks. Compared to mobile devices, their appearance is different and are especially designed to be used on the body.
Intelligent Clothing	To be considered intelligent, a piece of cloth needs to add some feature that is traditionally unclothing-like to the garment. It cannot compromise other specific characteristics like wearability and washability.

Wearables can be classified in many different ways. According to their functionality, they can be single or multi-functional, active or passive, invasive or non-invasive, communicate in a wired or wireless mode and be disposable or reusable. Finally, they can be classified according to their field of use, like public safety, entertainment, military or position tracking. Our main focus will be on wearable technologies applied to the healthcare area, also known as WMDs [16].

2.2 Wearable Medical Devices

In recent years, the total amount of healthcare expenses, expressed as a proportion of the gross domestic product, is considered to have reached extremely high values. This is a consequence of not only an increase in healthcare costs but also a result of an overall economic slow-down [19]. These high values, alongside with the ageing of population, [2] are generating a new trend in the delivery of healthcare, changing the healthcare delivery setting from hospital to home. Consequently, the relevance of personal healthcare is rising dramatically [20] which, in turn, is catalyzing the development of WMDs. According to Hung and colleagues [21], the aging of the world's population leads to an increasing need for both chronic and geriatric care. Chronic diseases are becoming the leader cause of both death and disabilities and will reach an alarming value by the year of 2020, accounting for about three-fourths of all deaths. This includes cardiovascular disease, diabetes, hypertension, etc. Innovation in WDs, in this case for home care, allows long-term, continuous and unobstructed monitoring of many different biosignals. A further analysis of different devices and its impact will be made in section 2.4.

Many different discoveries and developments enabled the progress of wearable medical devices and are mainly related to advances made in the field of engineering. The major breakthroughs are related to:

- Sensors coupled to microelectronics, telecommunication and data analysis;
- Battery technology;
- Telemedicine;
- Smartphones, apps and cloud services; and consequent
- Communication platforms.

The first breakthrough that was referred is directly related to vital signs monitoring since these measurements are usually made by sensors. Developments in this area allowed the creation of portable and wearable monitoring systems, using micro sensors that are able to be used in fabric. Also, the development and further extensive use of smartphones and apps made people more responsive to connectivity features, hence to the phenomenon of staying connected, deeply related to continuous monitoring of health signs. Data exchange was potentiated with developments related to cloud services [2]. Giuseppe and colleagues [22] state that WMDs "normally incorporate noninvasive physiological sensors, data processing modules, medical feedback, and wireless data transmission capabilities. They are small, light, unobtrusive, and designed for operation by unskilled users."

According to the European Council Directive, a medical device is "any instrument, apparatus, appliance, software, material or other article" designated to be used for human beings, with the goal of:

- Diagnosis, monitoring, treatment, alleviation of or compensation for an injury or handicap,
- Investigation, replacement or modification of the anatomy or of a physiological process,
- Conception control

and it is not used "in or on the human body by pharmacological, immunological or metabolic means, but which may be assisted in its function by such means" [23]. A WMD can then be defined as “a device that is autonomous, that is noninvasive, and that performs a specific medical function such as monitoring or support over a prolonged period of time.” [20] Nowadays, most common WMDs are related to monitoring of vital signs like heart rate or blood pressure or even to monitor human posture and kinematics with accelerometers [2]. The different applications, according to [14], are listed below:

- Vital signs monitoring (ECG, EEG and EMG);
- Safety monitoring;
- In vivo implants;
- Chronic disease monitoring;
- Home rehabilitation;
- Assessment of treatment efficacy;
- Early detection of disorders;
- Obesity control.

When designing a WMD there are some challenges that must be faced in order to potentiate its acceptance. The first one is related to the wearability of the device and its ergonomics. It should allow freedom of movement and it should interfere the minimum in user’s life. Regarding technical considerations, it has to be safe and reliable. WMDs usually have to collect data, process signals and store/process information so these are features that also need to be considered. If information is collected, the WMD must also ensure privacy and security of the collected data. It is important for the device to have a feedback mechanism, especially if it is going to be used for monitoring. Finally, power consumption must also be considered [20].

2.3 Market Characterization

According to Transparency Market Research, WMDs can be segmented into two different groups, namely diagnose and therapeutics. The first one is based on product types and includes devices like vital signs monitors, neuromonitoring devices and fetal and obstetric devices. The second one can be divided according to the product type or according to the application, like remote patient monitoring and home healthcare [24].

Currently, the market for wearable devices has been focused on consumer electronics trying to fulfill the needs of specific customer segments like athletes or fitness consumers [25]. High acquisition costs and motivation are two of the factors that might influence the adoption of WDs, narrowing customers segments. In spite of only 1% to 2% of US population has used these devices, annual sales are expected to grow more than $50 billion until 2018 [26]. In the specific case of medical devices, that can be worn or used at home, the market segment has increased in the past years, however, this growth has not decreased hospital care. One can infer that medical devices are acting more like complementary devices instead of acting like alternatives to hospital equipment [20]. Nevertheless, healthcare consumers are more informed and empowered than ever. Nowadays, people who are connected use several digital tools in order to take control of the healthcare service they are using. For example, over 70 % of Americans with access to the Internet use it in order to obtain information related to healthcare and more than 40% try to diagnose themselves before confirming it with their physician. Patients want to balance the value of cost-effective prevention with expensive treatments, demanding more information that can be given by WMDs, influencing adoption rates [27].

According to a forecast [28] that analyzes the global wearable healthcare market, in 2015 this market was worth $3.3 billion and it is expected to grow at a compound annual growth rate (CAGR) of 17,7 %, going to be worth approximately $7,8 billion by 2020. They state that the “market is showcasing evident potential in the current context.” Furthermore, they still refer that wearable medical devices offer solutions not only to the physicians but also to healthcare providers. They categorize them into four different segments:

- Disease Management;
- Monitoring and Feedback (more than 70% of all the wearable devices market);
- Rehabilitation;
- Health and Fitness processes.

Another major indicative of the potentials of this market is the investment that venture capitalists made in digital health and wearable tech. In 2014 health startups raised more money (about $2.3 billion more) than in 2013. A significant share of the money was invested in digital medical devices like wearables. As they become cheaper and more sophisticated it is expected that these devices and the corresponding apps will become a part of both consumer’s life and the healthcare system [29]. However, like any other innovative product, the success of wearables depends on many different factors related to the user itself. According to Park and colleagues [16],

The success of any innovative product in the marketplace depends on:

- Its effectiveness in successfully understanding the user’s needs and meeting them;
- Its compatibility with or similarity to existing products or solutions;
- The extent of behavioral change needed to use the new product;
- The reduction in the cost of current solutions or technologies it aims to supplant;
- The improvement in the quality of service (or performance);
- The enhancement of the user’s convenience.

Therefore, the final frontier of wearables lies in demonstrating their value to both the end user and the ones paying for the technology. Figure 2.3 presents the interactions alongside with other key activities and stakeholders that need to be considered in order to potentiate the commercialization process. In the specific case of WMDs, the end user is usually the patient and the payer can be a healthcare insurance company.

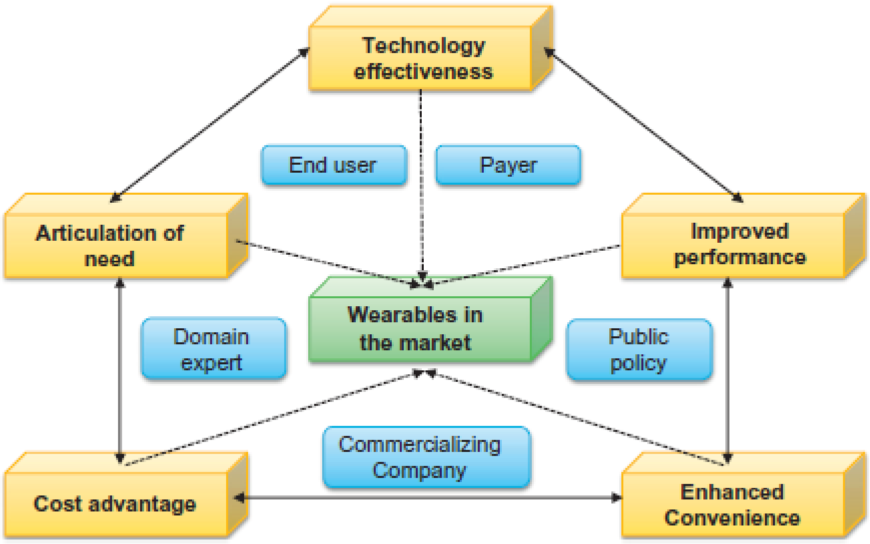


Figure 2-3 -Key activities and stakeholders in the process of commercialization. Available on [4].

There are also specific characteristics that make this type of technologies so desirable, such as mobility, compactness and portability. Figure 2.4 indicates the main factors that influence both the adoption and buying decision of wearable technologies.

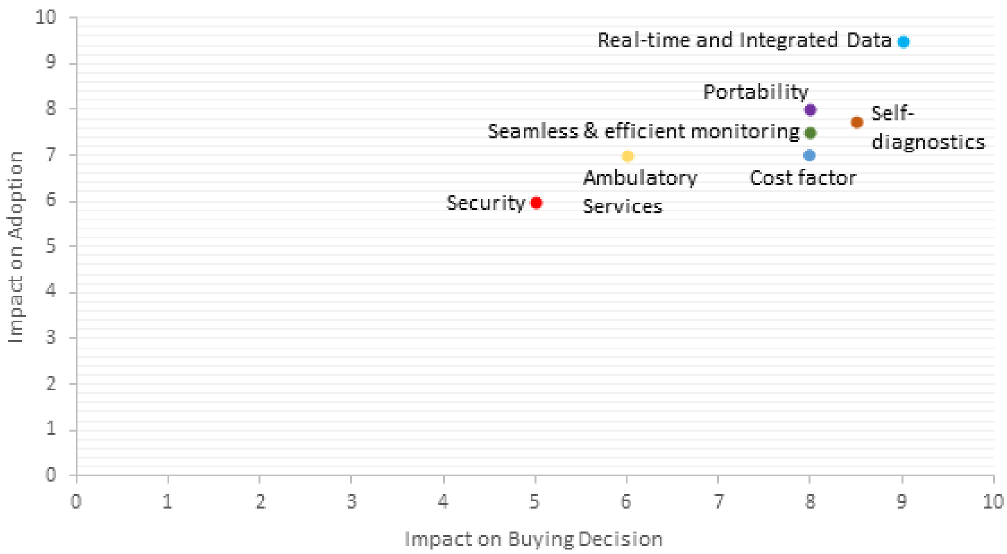


Figure 2-4 - Major factors that have impact in the adoption and buying decision of wearables. Available on [30].

Besides what was previously mentioned, the market will only succeed if it is able to overcome some challenges that are mainly related to data collection. This data that is being collected at every moment must have a proper analysis, otherwise, it will be useless for the user or for the physician. According to Rajan [30], the demand for real-time, insightful and actionable data will drive the market faster.

2.4 Social and Economic Impact

Wearables can be the key to change and disrupt the current state of healthcare by "eliminating waste, improving patient care, and rationing of reimbursement models" in order to "integrate reliable patient data that can be linked in real time across the continuum of care and support providers' decision-making". This kind of technology is expected to facilitate data sharing, potentiating connectivity between healthcare players [31].

According to a study performed by Morgan Stanley [31], the three main market areas that can benefit from the use of wearable devices are:

- medical device integration and innovation;
- employer-sponsored health programs; and
- pharmaceutical compliance.

Medical device integration and innovation are related to the use of these technologies in existing technologies and the improvement of existing methods that can potentially benefit the patient. In the managed care business, a driver for wearable adoption is the use of employer-sponsored health programs that offer a lower healthcare cost for both the consumer and employer. In this case, some sort of incentive is made in order to encourage healthier workplaces. Nowadays, these programs can include rewards of up to 30% of the healthcare coverage and use wearables in order to monitor employees. Regarding pharmaceutical compliance, there is an estimation that in the US about 20-30% of the written prescription are not filled. In addition, about 50% of all the pharmaceutical treatments are not completed by the patient. Therefore, patient compliance is a major limitation of the effectiveness of therapies based on pharmaceuticals. There are currently some solutions that are especially useful for the elderly that combine pills with small ingestible sensors. This way, a drug administration pattern can be recreated since there is an activation of the sensor when the pill is ingested, ensuring the physician or a relative that the prescription was followed [31].

Another major opportunity is related directly to consumer health and preventive medicine, a key point in reducing healthcare costs. As stated before, the conventional hospital-centered system focused on diagnosis and treatment is now shifting to a new paradigm, i.e., healthcare systems focused on the individual. Furthermore, in the long term, wearables can change patient management with new monitoring devices in order to optimize the treatment of different diseases, like obesity and heart diseases and other chronic diseases. As previously referred, the number of patients with chronic diseases has increased in the past years. These diseases are propelling the transformation of healthcare systems due to the need of monitoring patient's health in order to adjust the treatment to their symptoms. Wearable technology is recognized as an enabler since it allows individual and home monitoring [2]. Philips, a leading healthcare devices provider, states that homecare monitoring can potentially reduce 38% of hospital visits and can potentially save $27 000 of the cost per patient per year (in the US) [31].

According to Michael Davies [1],

> *"By providing a more complete picture of patients' health, wearable devices could also help cut healthcare costs as providers utilize preventive measures more effectively. (…) Wearable devices could also provide holistic health data to patients as well as clinicians. Empowering patients by providing them with access to data that they can understand and affect can increase adherence to other preventive behaviors. This is good for health outcomes in general, and it could be cost-effective in other areas, too. Wearables can enable social motivation and engagement (...)"*

The impact of these devices can be exemplified in some of the following cases. In the specific case of diabetes, wearable technology is making an impact in the field of therapeutics with a wearable device that has a reservoir of insulin that lasts for three days, replacing syringe or pen administration. Accurate blood monitoring is also essential for a diabetic patient. Nowadays there are continuous glucose monitoring devices that give patients real-time information about the levels of glucose. The device consists of an adhesive patch that has a small sensor inserted below the skin [31]. Teng and colleagues [2] focus their attention on devices that enable disease management, for example, cardiovascular or neurological diseases, like congestive heart failure and Parkinson's disease. The management of these diseases is dependent on early detection and a quick response to changes in the patient's status. For this purpose, they give the example of systems of sensors that can be comprised into devices embodied in clothes, watches or finger rings. Then, the signals collected by the sensors are sent to the healthcare provider. Regarding Parkinson's disease, they also state the impact that these devices can have in assessing information about tremor since the information that is given by patients does not reveal accurately the severity of their symptoms. Regarding monitoring, some devices are already quite common, like portable ECG systems and blood pressure measurements systems. However, there are some new technologies that use as basis the principles in these technologies alongside with wearable technologies principles. Lukowicz and Troster [15] refer as an example a wrist-worn medical monitor and alert system for the use of cardiac and respiratory patients. They also refer the positive impact that wearable technology can have in pain management, linking the amount of activity to the degree of pain felt by the patient.

So, wearables are capable of providing long-term information about the overall health of a patient. The development and adoption of smart wearables that are able to collect meaningful patient data allow providers and payers to save money by enabling patient engagement and preventive care. They also have the ability to empower patients by providing them data about their own health. However, many different manufacturers focus their attention on the design of wearables for consumers and not for the medical market. This leads to the limitation of functionality of these devices that need to track more biosignals in order to provide more meaningful data [1]. Nevertheless and according to PWC [29], wearables can improve efficiency, productivity, service and engagement across different industries. In the specific case of the healthcare industry, they state that it can improve access to medical information, increase clinical trial participants, ensure a better diet and exercise and enable more accurate diagnosis.

2.5 The Specific Case of ECG Technology

In developed countries, the impact of some cardio-vascular diseases like myocardial infarction and congestive heart failure has increased, increasing mortality and morbidity. Consequently, there is a demand for long-term continuous monitoring of a patient’s ECG, enabling the evaluation of the performance of the cardiovascular system. The ECG signal is a parameter that can be accessible by placing electrodes on the patient’s body [3] and it is one of the most used signals for non-invasive diagnosis of different cardiac diseases [4]. According to the American Heart Association [32], an ECG is a test that can measure the electric activity of the heartbeat. In each beat, an electric impulse travels through the heart causing it to squeeze and pump blood.

2.5.1 Heart Physiology and the ECG

The heart is composed by four separate compartments or chambers. There are two upper chambers, one in each side of the heart called atrium. They receive and collect blood coming to the heart. Then, the atrium delivers blood to the lower chamber, called ventricle, which pumps blood away from the heart through rhythmic contractions [33]. Cardiac cells are electrically polarized in their resting state. This means that their inside is negatively charged compared to the outside. Membrane pumps allow to maintain this polarity by ensuring a right ion distribution. However, these cells can lose their negativity in a process named depolarization that is considered to be one of the fundamental electrical events of the heart. The depolarization is propagated from cell to cell producing a wave of depolarization that represents a current and can be detected by using electrodes. After this event, cells repolarize, restoring their resting state. This phenomenon can also be detected through electrodes. The waves registered in an ECG are nothing but the manifestation of these two different processes [34]. Each portion of the heartbeat, as we can see in figure 2.5 corresponds to a different deflection on the ECG. In a normal ECG five visible forms are registered, namely [35]:

- P wave – Representing the atrial depolarization;
- Q wave – Representing septal depolarization;
- R wave – Representing early ventricular depolarization;
- S wave – Representing late ventricular depolarization;
- T wave – Representing the repolarization of ventricles.

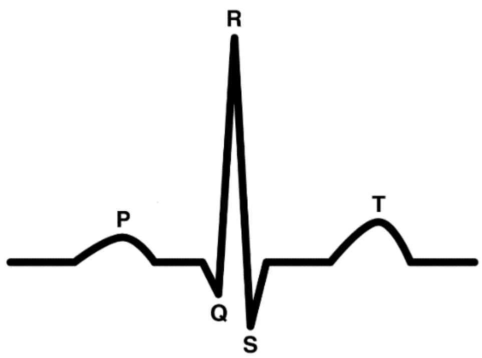


Figure 2-5– A graphical representation of the ECG waves. Available on [85].

2.5.2 WEARABLE ECG TECHNOLOGY

As stated before, continuous monitoring of the ECG activity and activity status can be crucial in managing heart related diseases [36] and it can also help in reducing the costs of healthcare expenses [37]. Traditional solutions like Holter monitors are not convenient to wear since they require too many electrodes attached to the body and are quite heavy. It becomes evident that a continuous monitoring system should interfere the minimum in its user lifestyle. According to Miao and colleagues [36], there is an increasing demand for small-size, compact and wearable ECG acquisition systems. Deepu and colleagues [37] add that the main challenge in building a remote monitoring system is the development of compact, low power wearable sensors that can acquire, process and transmit the sensed signals to the monitoring device. It is required a high level of integration in order to minimize both costs and size of the sensor. Wireless transmission technologies can also play an important role in the development of a wearable ECG system by replacing all the wired connections with a simple gateway in order to transmit the information of the biomedical signal [38]. When designing a wearable ECG monitor system, according to Meda and Manjunath [39], there are three main factors that should be satisfied: a high throughput, wearability and low power consumption. Geethika and Manjunath [40] state that a wireless wearable ECG system should include: a monitored object (lead lines included), a monitor, wireless modules and a mobile phone/PC with GSM/GPRS/CDMA module. These based wireless communications enable the transmission of ECG signals. The device has also to store data and perform preprocessing of the acquired signal [41]. Using the user manual of one wearable product that used ECG technology as an illustration [42] it is also possible to understand what are the main specifications that these products require. They are especially related with performance characteristics, circuitry, output, power requirements, physical characteristics, environmental specifications and user interface.

3. PATENTS

In this section, an overview of patents will be made by exploring definitions, contents and different classifications. Alongside with this overview, it will be presented the motivation behind the study of patents and the outputs of this analysis, focusing on the link between patent analysis and extrapolations about innovation trends.

3.1 PATENT OVERVIEW

Patents are public documents [43] designed to protect inventions or technologies [44]. According to the World Intellectual Property Organization (WIPO), a patent allows its owner to decide if the invention, that can be a product or process, can or cannot be commercially used and by whom the commercialization will be made. The protection, in norm, lasts for twenty years and it is valid for the country where it has been granted.

In order to be protected by a patent, an invention must follow three key criteria, namely [45]:

- It must introduce some new technical content that is not known in the field;
- It cannot be evident, i.e., for someone skilled in the technical field, the new solution cannot be obvious; and
- It should be possible to use (or be generated) in an industrial context.

Moreover, as a result of international conventions, other criteria can be applied, such as:

- The new invention must be patentable according to the local law of the country in which the patent is being granted since it is the State that gives monopoly for commercial exploitation; and
- The disclosure of the invention has to obey to established rules.

Regarding patentability, an invention that consists of materials that already exist in nature, scientific theories, plants/animals or even medical treatments/diagnose for human or animal use might be excluded from patent protection [45].

Regulation on patents states that an application must contain, among others, a description of the invention, patent claims, an abstract and, if needed, drawings referring to the description [46]. The patent's data can be divided into two groups: structured and unstructured items. Structured items are those which are consistent in both semantics and format [47]. Contrarily, unstructured items don't have a fixed formatting [48]. The different contents of a patent according to the Patent and Trademark Office (PTO) are presented in table 3.1.

Table 3-1 - Fields/sections of patents and corresponding description. Adapted from [49]

Section/Field	Description
Title	Name or title of invention.
Inventor Information	Inventor's identifying information like name and address.
Patent Number	Number assigned to the patent.
Patent Filling Date	Corresponds to the date the patent was filled by the Patent Office.
Patent Issue Date	Corresponds to the date the patent was issued by the Patent Office.
Classification	Classification assigned to the patent by the Patent Office. See chapter 3.2 for details.
Referenced Patents	The number of existing patents that are referred, including classes and subclasses.
Abstract	Invention's summary. Appears on the front page and is the most referenced section.
Drawings	Black and white drawings of the invention.
Background of the invention	Prior Art. It is an explanation of previous inventions that can be related to the new one.
Summary of the Invention	Discussion that captures the essential features and functions.
Brief Description of Drawings	Usually one sentence in order to explain the drawings of the invention.
Detailed Description of the Preferred Version of the Invention	A more exhaustive discussion of the aspects of the invention.
Claims	The legal scope of the patent.

There are several different routes for protection. The inventor - an individual, company, public body, university, etc. has to choose one route according to the strategy they want to follow. The basic option is a national route, where an application is filled with a national patent office. Another option is to follow an international route where applicants can protect their inventions in more than one country. Applicants can also choose to apply only to a regional office, for example, they can apply to the European Patent Office (EPO) which grants European patents. The validation process requires both translations into the national language of each country and the payment of national fees. After being granted, the patent can be challenged by third parties. They can request legally for a patent to be revoked or deemed invalid and the applicant has also the right to enforce the disputed patent in court. This process is purely national, including in Europe [50].

3.2 CLASSIFICATION

To facilitate search, patents are classified according to technical area. According to Montecchi and colleagues [51], different patent offices have their own patent classification systems, being the major ones presented in table 3.2.

Table 3-2 - Different patent classification systems and correspondent issuing offices. Adapted from [51]

Patent Classification Systems	Issuing Office
International Patent Classification (IPC)	World Intellectual Property Organization (WIPO);
European Classification*	EPO
In Computer Only (ICO)*	EPO
United States Patent Classification (USPC)	United States Patent and Trademark Office (USPTO)
F-Index*	Japanese Patent Office (JPO)
F-term	JPO

* derived from IPC

As we can see in table 3.2, there are many distinct classifications that have several differences between them. In order to overcome this problem, EPO and USPTO decided to create a new classification system, the Cooperative Patent Classification (CPC) [52]. CPC is divided into nine sections, from A to H and Y, which are also divided into classes, sub-classes, groups and sub-groups. It covers 250 000 classes, being the most precise classification that uses English Versions [53]. In table 3.3 the different sections and the correspondent designations are shown.

Table 3-3 - Sections of CPC according to EPO. Available on [53].

A	Human Necessities
B	Performing Operations, transporting
C	Chemistry, metallurgy
D	Textiles, paper
E	Fixed Constructions
F	Mechanical engineering, lighting, weapons, blasting engines or pumps
G	Physics
H	Electricity
Y	General tagging of new technological developments; general tagging of cross-sectional technologies spanning over several sections of the IPC; technical subjects covered by former USPC cross-reference art collections [XRACs] and digests

These classifications exist in order to describe, in few words, the invention that is being considered and can be used to search documents. The classification process, held by patent officers, consists of assigning a patent classification code to the patent. Each code has a defined description. As previously mentioned, it follows a hierarchical model with different levels, beginning in the most general to the most specific. An example of classification is given in table 3.4 in order to better understand how these levels work [51].

Table 3-4 - Example of Classification using CPC. Available on [51]

Level	**Level Name**	**Code**	**Description**
1st	Section	B	Performing Operations; Transporting
2nd	Class	B08	Cleaning
3rd	Sub-Class	B08B	Cleaning in general; prevention of fouling in general
4th	Main-group	B08BB003/00	Cleaning by methods involving the use or presence of liquid or steam
5th	Sub-group – 1 dot	B08BB003/04	.Cleaning involving contact with liquid
6th	Sub-group – 2 dot	B08BB003/10	..with additional treatment of the liquid or of the object being cleaned, e.g. by heat, by electricity, by vibration
7th	Sub-group – 3 dot	B08BB003/12	...by sonic or ultrasonic vibrations …

3.3 Patent Analysis Motivation

3.3.1 Patent Analysis and Innovation

According to the Organisation for Economic Co-Operation and Development (OECD), innovation is defined as [10]: "(…) the transformation of an idea into a tradable product or service, a new manufacturing or distribution process, or a new way of providing service". They further state that technological innovation is [54]: "(…) all of the scientific, technological, organisational, financial and commercial steps, including investments in new knowledge, which actually, or are intended to, lead to the implementation of technologically new or improved products and processes."

Therefore, the innovation process is potentiated with the creation and development of innovative ideas, which are the precursors of commercial success [47]. It also plays a major role in the development of the economy and in sustaining the growth of a world that has an increasingly growing population, demanding more resources and that faces several environmental challenges [55]. The incentive for innovation becomes evident and it is believed that patents can potentially help in this process [56]. Equally, patents have been also broadly used as indicators due to their widespread availability [57], being helpful in identifying both technological information and present condition of technology assets [43]. Therefore, patent analysis is one of the most used methods to inquire about technological innovation [12].

For companies, it becomes extremely necessary to study their own patent portfolio once the value of knowledge is in part related to the value of patents. According to Grimaldi and colleagues [56], this value depends on the context and tries to meet business' needs namely:

- Employees' Motivation;
- Customers' Attraction;
- Partners' Attraction;
- Investors' Attraction;
- Competitors' Intimidation;
- Income Generation.

Although their work is intrinsically related to obtaining strategic information from patents, they also state the importance of patent studies in assessing the value of technological innovation alongside with information about investments, economic returns, scientific research and results. Lee and colleagues [43] refer that patent analysis is able to establish a company's technology strategy by providing information about technology assets, support planning based on the knowledge of competitors' patent portfolio and help managers prioritize the development of projects. Besides technologic strategies, Kim and Lee [58] state that patent analysis has been used for both long-term and short-term purposes like monitoring technology trends and assess technology innovation patterns. Markatou and Vetsikas [59], sum up the advantages and disadvantages of patent analysis. Regarding advantages, they refer the proximity that exists between patents and innovative activities, the range of fields covered and the geographical scope. As stated before, they also point out the easy accessibility of patents which enables several different types of analysis, for example, technological, sectoral-industrial or national. Comparing to other data sources, patents are often considered to be the only timely measure of rapid technological change and are extremely important in the assessment of technological systems' performance [59]. On the other hand, the data presented by patents has some limitations too. The first one is related to the fact that not every invention is patented. Other forms of protecting new products or inventions are available. For example, companies can choose to trade secrets instead of patents. In spite of being treated as equals, not every single patent has an economic or technological impact and they might differ according to the country, sector, technologies, etc. These differences can alter the analysis results in terms of performance, being hard to define if we are comparing similar patents or not. It is widely accepted that there are several differences between the different patent systems due to legal variations and geographic, economic and cultural factors.

Patents also present an innovation trade-off. In one hand, by the grant of a geographical monopoly, patents encourage the exploitation of new inventions, on the other hand they have high costs associated (mostly related to maintenance fees and potential litigations). A patent gives an exclusive use of a certain technology or method to a company, allowing that company to charge higher prices, simultaneously excluding customers that would only be capable of paying the marginal cost of the innovative good [50]. According to the OECD, this is considered to be the central dilemma created by patents: they foster innovation, growth and value creation improving the dynamic efficiency of the economy, however, they also create a sort of static efficiency driven by the reduced competition and, consequently, higher prices which exclude some of the potential customers. Thus, public policies have been put in place to address this dilemma such as the time limit of a patent, its breadth and the compulsory licensing mechanisms foreseen in the Trade Related Aspects of Intellectual Property (TRIPS) Agreement [50].

Ultimately, patent analysis can provide answers to many different questions allowing to understand which companies are present in the industry, what are the countries where innovation in the sector is being performed, what is the potential of R&D, etc [10]. Based on the answers to these questions, different aspects of the dynamics of the innovation process can be mapped, such as co-operation in research, technology diffusion across countries or industries alongside with studies of the competitive process [11].

Patent data may also be combined with other data (e.g. scientific publications, innovation surveys) according to the stage of innovation being addressed in table 3.5.

Table 3-5 - Different measures for innovation. Adapted from [11].

Stage of Innovation Cycle	Measures
Technology Development	R&D expenditures and personnel
	Scientific publications
	Patented inventions
Technology diffusion	Patenting activity
	International trade
Technology adoption	Licensing surveys
	Sales and market penetration
Non-technological innovations	Innovation surveys

Therefore, in a constantly changing and financial lucrative market, ensuring the competitive advantage using intellectual property is an important piece of a strategic plan for major players. Assessing this intellectual property becomes also an important exercise for both future and current players [60].

3.3.2 CURRENT METHODS IN PATENT ANALYSIS

Usually, patent analysis starts with task identification, that means defining not only the goal but also the scope and concepts of the analysis. Then, it is important to build a portfolio of patents by searching and filtering the most relevant ones, making a segmentation to normalize structured and unstructured items [5]. Usually, patent classification works as a filter in the search process, so it becomes essential to select the right and most relevant classification categories to the object in analysis. Furthermore, it is unanimous among patent researchers that any patent search can be considered as complete [51].

In order to perform a serious research, the most relevant techniques must be applied. The preferred method is a combination of both classification and keyword search. When separated these methods have several disadvantages. For instances, keyword search is usually performed in English. As such, this may mean that we can be overlooking patents that are poorly translated into English – note that, in the US, almost 40% of the applicants are from foreign countries. Equally, the same term can have multiple synonyms and sometimes the titles and abstracts are not ideal. There is also some mistakes and omissions that may hinder the search by keywords. On the other hand, classification search can suffer due to obsolete classifications and minimal classification. It's important to refer that the classifying process can, sometimes, be rather subjective and incomplete, which decreases the accuracy of this search method too [61].

Different databases are available to search patents in order to build a solid search result. Some examples are Espacenet, that offers access to millions of patents worldwide, dating from 1836 to today [62], USPTO, an American database that has a collection of patents from 1790 [63], Google Patents, WIPO, among others. After having the patent result, an analysis of each patent and group of patents should be performed, based on patent characteristics. It is possible, then, to obtain a patent map and to interpret the results, predicting trends or relations inside the sector in analysis [64]. In order to analyze patents' data, different methodologies like text-mining, network analysis, citation analysis and index analysis can be used [43]. Lee and colleagues [19], used text mining with component analysis, in order to obtain keyword vectors. Then, they performed a vacancy analysis to define areas that have a lower patent density but are large in size. These areas were then studied to understand the kind of technological features associated and, consequently, the potential for innovation. Another text-mining example is the work of Tseng and colleagues [64] that describes some techniques that can be used in patent analysis including text segmentation, summary extraction, feature selection, term association, cluster information, topic identification and information mapping. The main goal of this study was to uncover and visualize useful patterns in textual data [65]. Lee and Lee [12], developed patent maps, after selecting patents from the analyzed sector – energy sector. Then they developed clusters according to similarities in technologies in order to study the evolution of innovation over time in that sector. Kang [66] made an empirical study by analyzing different patent information. The study started by considering international patent information important to establish marketing strategies and to assess information about the geographical distribution of the innovation process in the sector (smartphones). Then, the grant ratio was also analyzed as a measurement of patent's quality in the sector. Co-applicants and co-inventors were considered important once resources and competencies are dispersed among organizations and in the geographical space. At last, knowledge accumulation (as the proportion of citations of the patents filled by the same applicant) and spillover (as the proportion of citations of the patents filled by another applicant) were analyzed.

Visualization techniques help in presenting the results and interpreting them. Many different representations can be used such as 2-D matrix, folder trees or topic maps (topics are clusters of information obtained through patent analysis). Regarding maps, they can focus on trends, showing how topics grow and evolve over time, they can be query maps showing the patents which satisfy specific conditions, aggregation maps showing results based on a specific tribute or zooming maps showing in detailed a part of the overall map [64].

In order to summarize the different tasks, table 3.6 is presented with a typical patent analysis scenario starting with task identification and ending in the interpretation of the obtained information.

Table 3-6 - Patent analysis scenario. Adapted from [64].

Task Identification	Define scope; concepts and purposes for the analysis
Searching	Search, filter and download relevant patents
Segmentation	Segment, clean and normalize the different data
Abstracting	Analyze the patent content summarizing claims, topics, functions or technologies
Clustering	Group or classify patents
Visualization	Create technology-effect matrices or topic maps
Interpretation	Predict trends and relations

In terms of research topics, both the studies performed and the indicators used resorting to patent data analysis are quite diverse. They can vary according to the publication format, the approach taken and the questions that are being addressed. According to the OECD Patent Statistics Manual [50], patent data can be used to study a diversity of topics, including:

- Technological Performance– Patents help in the process of tracking technological leadership or positioning in a specific sector.
- Emerging Technologies – The information present in patents helps to identify issues such as the involvement of different entities or how innovation is performed.
- Knowledge diffusion and the dynamics of technical change – Patents provide a detailed description of how the invention was made alongside with a study of previous related inventions.
- Geography of invention – As patents can be divided according to the country or region where they are granted, patent data can be used to study geographical characteristics of the innovation process or the impact of a certain regional technological specialization.
- Economic value of inventions – There is a correlation between the value of a patent and the number/quality of its citations. By linking the invention to the firm's data, it is possible to extrapolate information about the economic impact of a patent.
- Role of universities in technological development – Similar to the economic value of inventions, a compilation of the number of patents filed by universities can give information about the impact that they have in technological development.

- Globalization of R&D activities – Patents have information regarding the inventive performance and companies' activities. It is possible to track the different trends of the collaboration between inventors in different countries.
- Companies' patenting strategy – Through the information present in patents, it is possible to trace the market strategy of the company that owns the patent.
- Effectiveness of the patent system – Patent data can be used to study the impact of the patent system on both inventions and diffusion.
- Forecasting patent applications – With data complied over time, it is possible to predict the future demand for patents.

3.4 The Use of Patents in the WMD Industry

According to the theory of disruptive innovations [13], there are two different types of innovations: sustaining and disruptive. The first ones are those who occur regularly and are adopted by a wide range of companies in order to improve the performance of an existing product or service. On the other hand, disruptive innovations occur with less frequency and tend to have some sort of performance problems in the first moments. This group can further be divided into new market and low-end disruptions. New markets are created when the characteristics of the product limit the number of potential clients, one example is the creation of personal computers. Low-end disruptions are those which influence the low-end of the original business, attracting customers. One example is the entrance of the Korean automakers into the American market – a new market wasn't created but several customers where attracted (those who couldn't afford the product before).

In the case of wearable technologies, they have been around for many years. Yet, they are highly priced and are cumbersome [13]. Therefore, the wearable device market is considered to be in a critical point due to lack of adoption by early majorities to existing products. The market itself is constantly changing, caused by a quick technology growth, which makes the entrance in this sector even harder. It becomes necessary to study the innovation in this sector, in order to understand in which point it stands and what kind of opportunities are not being exploited.

According to Giuseppe and colleagues [22], the market's interest in this kind of solutions is expected to be enormous. The technological developments can potentially provide competitive advantage so patents are both valuable and relevant to this issue. It is worth noting that the number of patents related to wearable devices has increased in recent years, as we can see in figure 3.1. They further state that wearables are at the beginning of the transition from research to the commercialization phase, with a relevant number of units sold in order to support their integration into the clinical practice and healthcare processes.

In spite of not being specific to the case of WMDs, as stated before, it is possible to predict trends in this sector comparing to the overall market for wearables. Due to the relevance that patents have in innovation, it becomes evident the interest of their use in order to understand the dynamics of this industry.

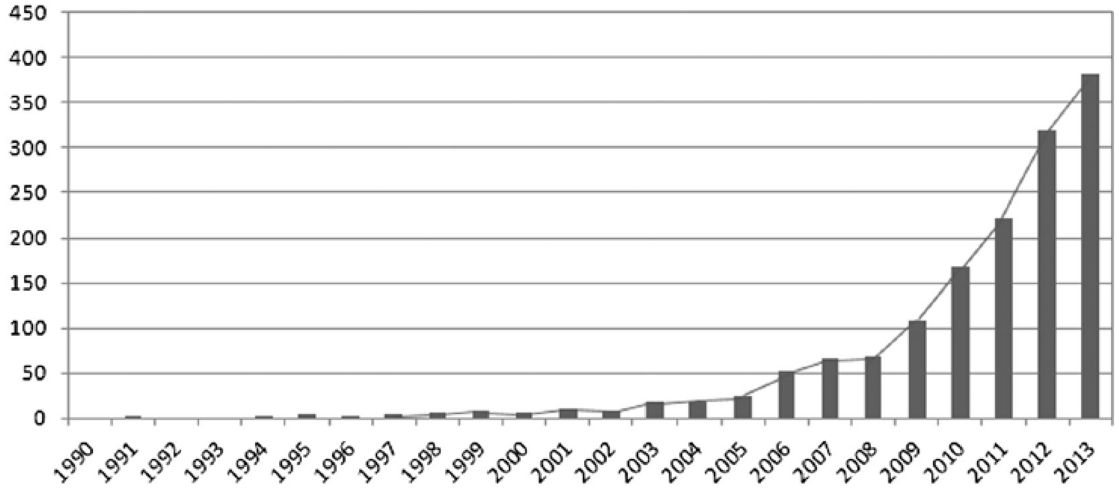


Figure 3-1- Number of patents related with wearables since 1990 until 2013. Available on [5].

3.4.1 PATENT LANDSCAPE ANALYSIS OF WEARABLE TECHNOLOGIES

According to LexInnova [60], wearable technology patents in the field of healthcare and medical devices score the highest number of applications. Top assignees for patents in the wearable fields are companies like Microsoft and Phillips, however, the top assignees for medical devices are Medtronic, Philips and Dexcom. Regarding geographical coverage, United States of America shows the highest number of patent applications followed by China. North America is considered to be the largest market for wearable devices, comprising over than 40% of global sales.

In a review of the intellectual property rights in the specific field of both wearable sensors and systems, Giuseppe and Piccini [22] searched for several different patents with specific keywords such as “wearable”. They restricted the search to specific IPC groups. For example, they consider the group A61B5 that is related to “Human Necessities” (Section A), “Medical or veterinary Science; Hygiene” (Class A61), “Diagnosis; Surgery; Identification” and specifically “Diagnosis; Psycho-physical tests”(Subclass A61B) and “Detecting, measuring or recording for diagnostic purposes” (Group A61B5). They further analyze the evolution of the number of patents, alongside with geographical distribution and top assignees. Their conclusions are aligned with those of Lexinnova, i.e, that United States of America has the highest number of granted patents and that the top assignees are companies like Philips.

4. METHODOLOGY

This study was based on a set of 495 companies with potential interest in wearable technologies. Of this initial dataset a selection of the ones commercializing both wearable and ECG products was made. This selection was performed by analyzing each of the companies' website and its respective product portfolio. If any of the products had an ECG sensor incorporated, then the company would be selected. Both medical and fitness/well-being devices were considered. Of the previously selected companies, an exhaustive analysis was further performed in order to understand whether the commercialize products were, in some way, legally protected by patent claims. So, in this phase, the focus was on companies' patent portfolio and the relation between claims and product features.

4.1 PRELIMINARY COMPANY STUDY

This study was based on a set of companies with potential interest in wearable technologies. These companies were taken from different databases (CB Insights [67], SNS Research [68], IDTechEx [69] and Kalorama Information[70]). Due to the various applications that wearable medical devices may have the search was narrowed to ECG technologies only.

In the first stage of the analysis, the database used was Google Patents [71]. This search engine allows different types of search fields, such as assignee, inventor, priority date, etc. It also allows to search terms that can be present in any part of the patent. Figure 4.1 illustrates an example of a search by assignee and keyword search, using the defined keywords: ECG/EKG and wearable. It is important to focus on the connectors used. In the case of the keywords ECG and EKG, the connector "or" is used because, in this context, the words act as synonyms. In the case of the keyword wearable, the connector used is an "and", because we want the presence of both keywords (ECG/EKG and wearable). The patent search was held from February 2016 to March 2016. It is important to refer that patents are only published 18 months after request, meaning that we analyzed patents until October 2014.

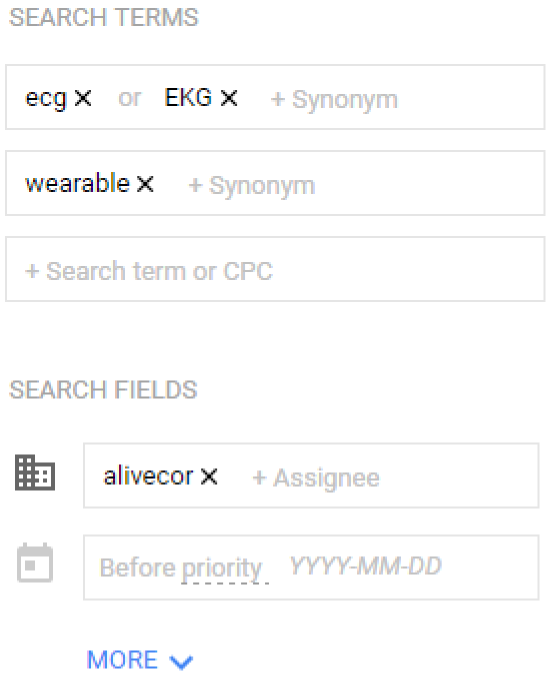


Figure 4-1 - Example of search by assignee (Alivecor) and keyword search. available on [86].

The search by assignee was performed for every company of the initial set, that can be consulted in appendix 8.1 – Companies List. If the company had patents, the keyword search was also held, first for each keyword (ECG or synonyms ; wearable), and then for both (ECG or synonyms and wearable), as illustrated previously. Companies' product portfolios were also studied. If the company had patents with both keywords and was commercializing products with ECG technology, at the time of this study, then it would be selected for a further analysis, as shown in figure 4.2.

Figure 4-2-Scheme representing the preliminary stage of this study.

4.2 PATENTING AND PRODUCT ANALYSIS

For this second stage of the study, we only considered the set of companies currently commercializing wearable ECG products (according to the information on the company's website) and that, simultaneously, were patent applicants with patents containing both keywords.

In order to filter patents related to ECG products, a new patent search was held. As shown in figure 4.3, the method used was a combination of search by assignee and a classification search, using CPC codes. In this case, the database used was not Google Patents, but Espacenet [72], due to the redundancy of results in Google Patents, i.e., the same patent returned more than once.

Figure 4-3 - Scheme representing the patenting and product analysis phase of this study.

The used codes are shown in table 4.1 and were chosen due to their relation with ECG. The final company set consisted of 15 companies, accounting for a total of 96 patents (see appendix 8.2- Patents List). In some cases (Medtronic, Polar Electro, Samsung Electronics), due to the high number of returned results a keyword search was also held, alongside with the classification search. The chosen keywords were product related and broad enough to minimize the potential loss of relevant patents. The keywords used were:

- Wireless and mobile, in the case of Medtronic;
- Heart Rate, in the case of Polar Electro:
- Sensor, in the case of Samsung Electronics.

Table 4-1 - CPC codes used to filter patents

CPC symbol	Designation
A61B5/0006	Remote monitoring of patient with the measured ECG signals being transmitted from the patient to a remote monitor or site
A61B5/0245	Measuring Heart Rate by using ECG signals
A61B5/0404	Hand-held or portable apparatus for detecting, measuring or recording ECG.

Each of the retrieved patents was analyzed in order to understand whether it was related to any of the products currently commercialized by the respective company. Of the overall 96 patents, 38 were considered as product related.

As previously mentioned, in chapter 3, each patent has a set of claims. Espacenet allows users to arrange them in a claims tree which enables the visualization of a tree representation of the independent claims and their dependent claims [73]. Thus, each independent claim of each of the 38 patents was analyzed and matched with a product feature. These product features, shown in table 4.2, were defined according to product specifications, except for the overall system and signal processing. These two features were considered in order to characterize the general architecture and the methods for processing the acquired signals, respectively.

Table 4-2 - Group of features determine to classify each patent claim

Feature	Designation
Overall System	Includes all claims related to product's components and structure, i.e., the way they are arranged.
Signal Processing	Includes all claims related to methods for analyzing and obtaining information from acquired signals.
Data Transmission	Includes all claims related to methods and components for data transmission.
Performance	Includes all claims related to input dynamic range, memory length, recording format.
Circuitry	Includes all claims related to frequency response, input impedance, A/D sampling rate, resolution, DC offset, CMRR, differential range.
Output	Includes all claims related to modulation, center frequency and frequency deviation.
User Interface	Includes all claims that can be related to means of communication between the device and user.

In order to match the selected patent claims with product features, we used the Delphi method. This method has been widely used to obtain medium or long-term forecasts, which involves establishing a consensus from a panel of experts [74]. Our panel included 5 experts in electronics, mostly academic researchers in the area of signal processing and a European Patent Attorney. Each expert was asked to match the independent claims of each patent with the product feature(s) that better characterize what was being claimed. They were given a brief explanation about the method and were provided with the patent claims, a link for the patent and a link for the product technical description (on the company's website). The answers of each expert were then analyzed and the results shown reflect the consensus obtained by the expert panel. When divergences were found, the decision for the product feature classification was taken by majority.

5. RESULTS

In this section, the results of both patent analysis and product portfolio analysis are shown. First, an overview of the general patent tendency is made, by analyzing which of the 495 initial companies have patents and their relation with wearable and ECG technologies. Then, a more detailed study is performed in order to understand the commercialization of patents and their relation with product features.

5.1 PATENT TENDENCY IN THE WEARABLE TECHNOLOGY MARKET

Of the initial set of 495 companies, acting in the wearable industry, 138 (approximately 28%) offered products with heart rate monitors, from which 55 (approximately 40%) were ECG related. Regarding patenting trends, as shown in figure 5.1, 328 companies have patents, i.e., approximately 66%. Of those companies, 119 (approximately 36%) had patents with the keyword "wearable", 36 (approximately 11%) with the keyword "ECG" or "EKG" and 81 (approximately 25%) with both. Therefore, most of the patents for which the analyzed companies applied appear to be related to wearable technologies in general. Nevertheless, there is a significant percentage of patents containing both "ECG" and "wearable" keywords in their text.

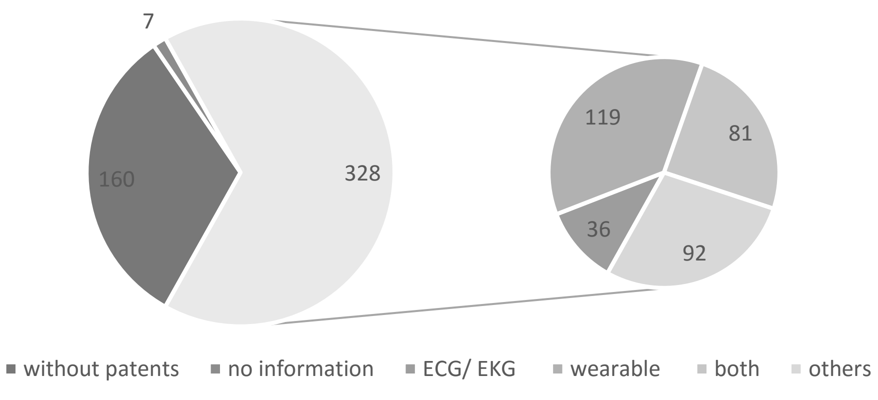
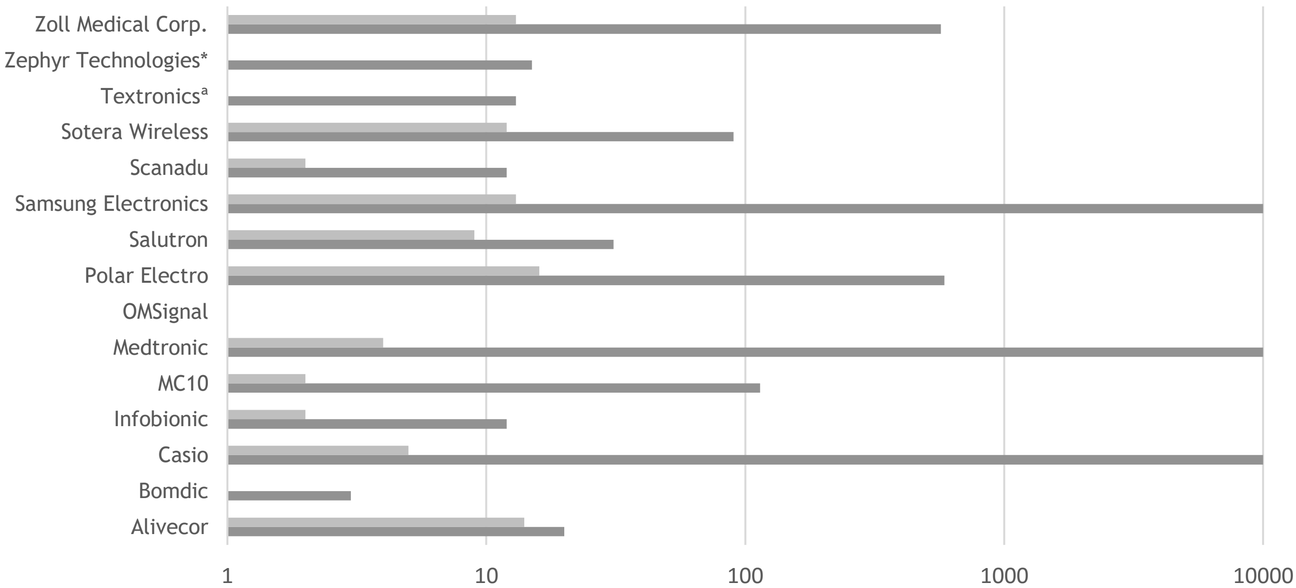


Figure 5-1 - Tendency to patent, as well as ECG/wearable patents for the selected wearable technology companies.

5.2 PATENT ANALYSIS AND PRODUCT PORTFOLIO ANALYSIS

For the next stage, the 81 companies that had patents with both “ECG” (or synonyms) and “wearable” as keywords were reviewed. The focus was exclusively on companies that already were commercializing ECG wearable products at the moment of this study since the main goal was to understand whether the inventions were already incorporated in commercial products.

In order to evaluate ECG-related patents only, a new patent search was held for each of these companies as applicant, combining it with the considered CPCs (see 4. Methodology). Similarly to the process followed by Andreoni [22], this approach allowed us to not only include patents with “ECG” (or synonyms) as keyword, but also the patents that could be related to these terms. Both these conditions were met by 15 companies of the initial sample, which accounted for 96 patents. In figure 5.2, it is possible to see the total number of patents of the 15 selected companies and the number of patents after narrowing the search with the selected CPC codes.



	Alivecor	Bomdic	Casio	Infobionic	MC10	Medtronic	OMSignal	Polar Electro	Salutron	Samsung Electronics	Scanadu	Sotera Wireless	Textronics[a]	Zephyr Technologies*	Zoll Medical Corp.
Patents with CPC + KW	14	1	5	2	2	4	1	16	9	13	2	12	1	1	13
Total	20	3	10000	12	114	10000	1	588	31	10000	12	90	13	15	569

number of patents

Patents with CPC + KW   Total

Figure 5-2 - Total number of patens vs patents with defined CPC codes used for the classification search.

Afterwards, the products technical specifications were analyzed. For each of the 96 patents, we checked, through "patent pending" mentions on the products information (e.g., website, instructions manual, figures on the patent body) whether the invention described in them was already implemented in the respective product. Two different groups were obtained - commercialized patents (i.e., patents protecting inventions that were implemented into a commercialized product) and not commercialized patents. The first group consisted on a set of 38 patents, and the later 58 patents. These results are presented in figures 5.3 and 5.4. In figure 5.3, we present the trend for commercialization, based on the priority date of the patent, for these two different groups; while in figure 5.4 it is represented the commercialization tendency for each analyzed company.

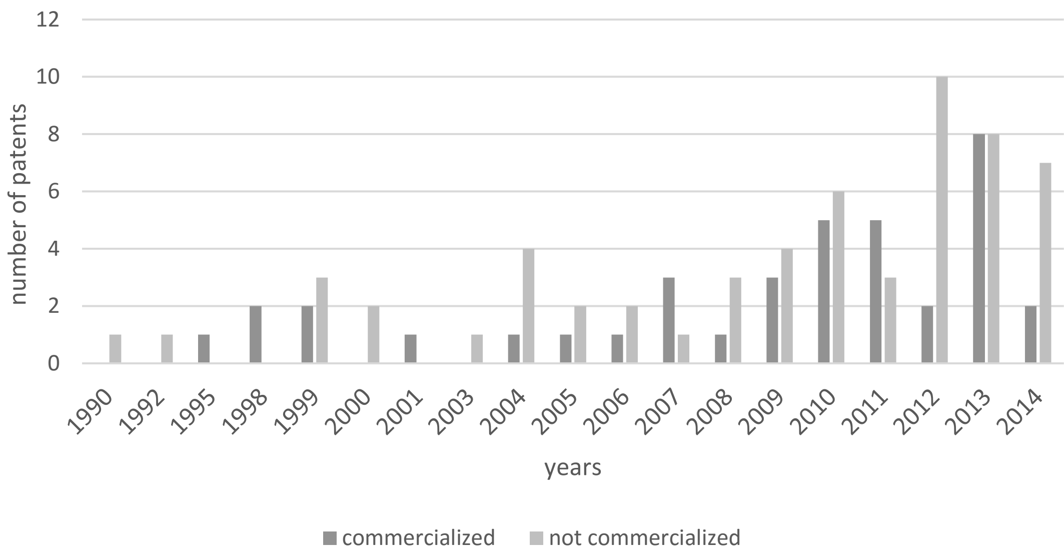


Figure 5-3 - Tendency through the years (1990-2014) of the commercialization of patents.

The results do not show a clear trend for commercialization vs. priority date. Looking at all 96 patents, it is possible to see that only 38 (approximately 40%) are actually implemented into products. This trend is consistent even if we only consider patents with priority date from 2010 onwards. When analyzing the results in terms of patent age, the tendency of patenting wearable ECG devices increased through the years, alongside with an increased tendency of patenting product features. Nevertheless, in 2012 there was a peak of the number of patents that were not related to any kind of product, followed by an increase in the number of patents implemented in products in 2013.

When addressing patent commercialization status by company, having in consideration the portfolio dimension according to the used CPC codes, it is possible to note that 6 out of 15 companies have more than 50% of their patent portfolio currently implemented in a commercial product. In fact, for the considered company sample, the average commercialization rate is 58% per company (with a standard deviation of 33%), accounting for the great dispersion that is exhibited in Figure 5.4.

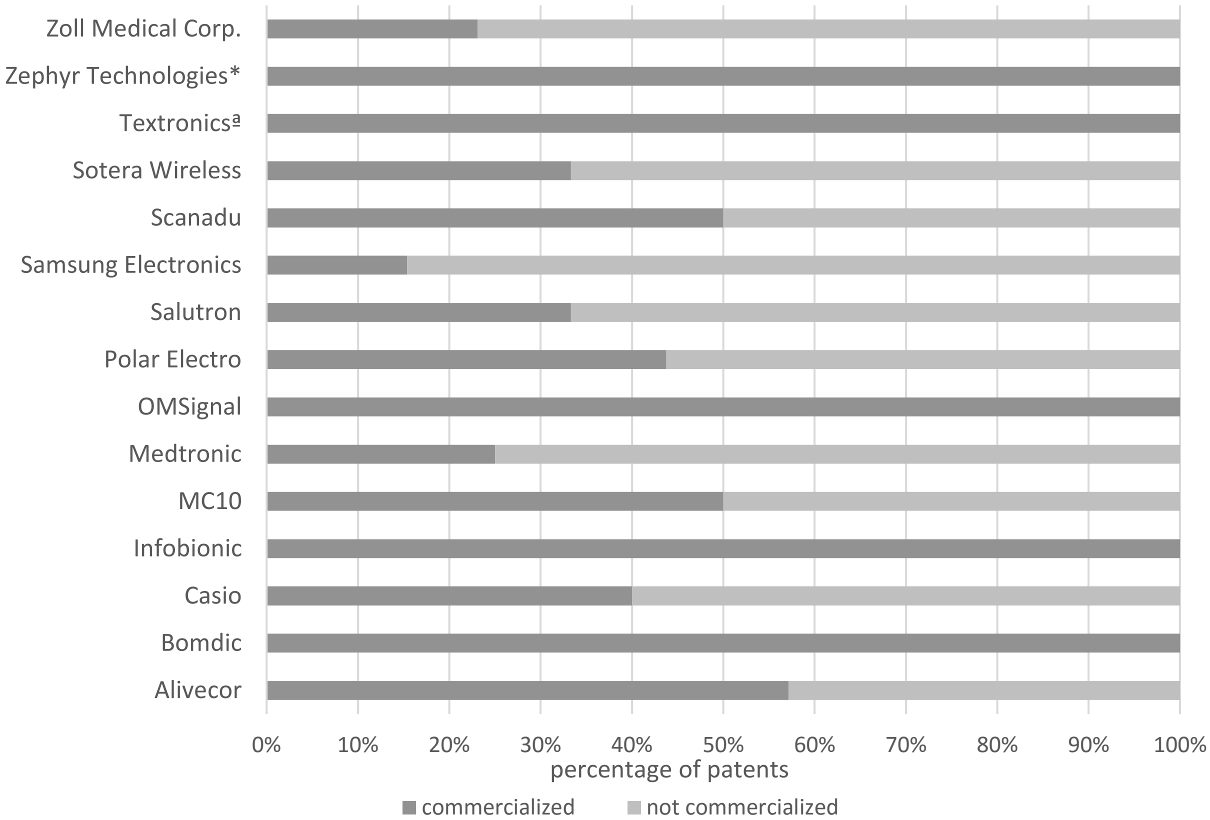


Figure 5-4 - Commercialized vs not commercialized patents for each of the 15 companies. * Now part of Medtronic [a] Part of Adidas

In order to understand the product features that the patents were claiming, for the set of 38 patents that were commercialized, a correspondence between claims and product features was made using a panel of experts, according to the category definition present in Table 4.2. A total of 158 claims were analyzed. The obtained distribution can be found in figure 5.5.

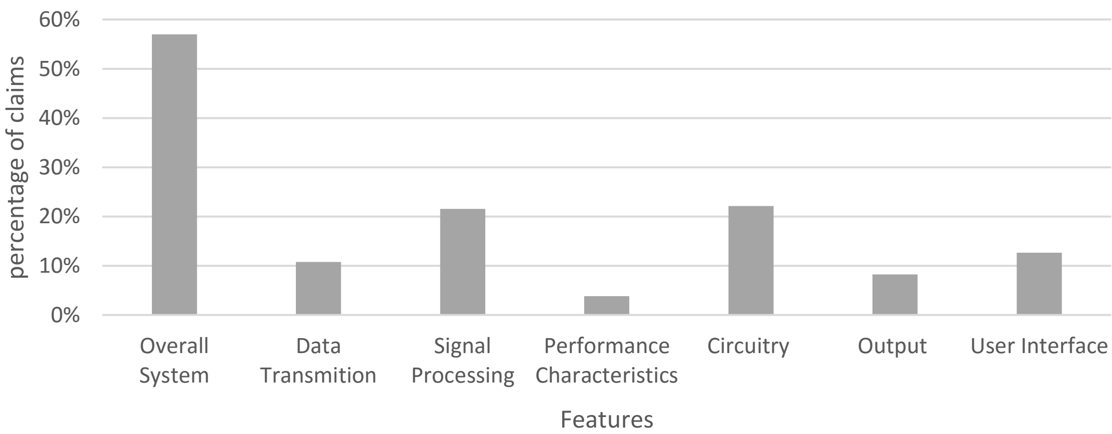


Figure 5-5-Correspondence between features and claims.

As shown, most claims tend to be broad enough in order to protect the products' components, structure and the way they are arranged (i.e., overall system). Such claims add up to 57% of all claims present in commercialized patents. After the overall system, signal processing and circuitry are the two areas with higher patent tendency (22%) followed by user interface (13%), data transmission (11%), output (8%) and, finally, performance characteristics (4%). As previously stated, it is important to mention that the same claim can have multiple classifications, i.e., it can refer to different product features.

When analyzing the distribution of the relationship of patents claims/product features and companies, it is possible to note a similar patent trend regarding the protection of product features. According to figure 5.6 and 5.7, companies, individually, also have a higher tendency to patent the overall system. 6 out of 15 companies have more than 50% of their patent claims related to this feature followed by signal processing, circuitry and output features. Figure 5.6 shows an average of the claimed product features per company. Figure 5.7 shows the distribution of claimed product features per company. It is interesting to see that every company has claims related with the overall system, but only two companies present claims related to output characteristics. Moreover, given the importance of data transmission in a system such as a wearable, not every company presented patents related to this feature.

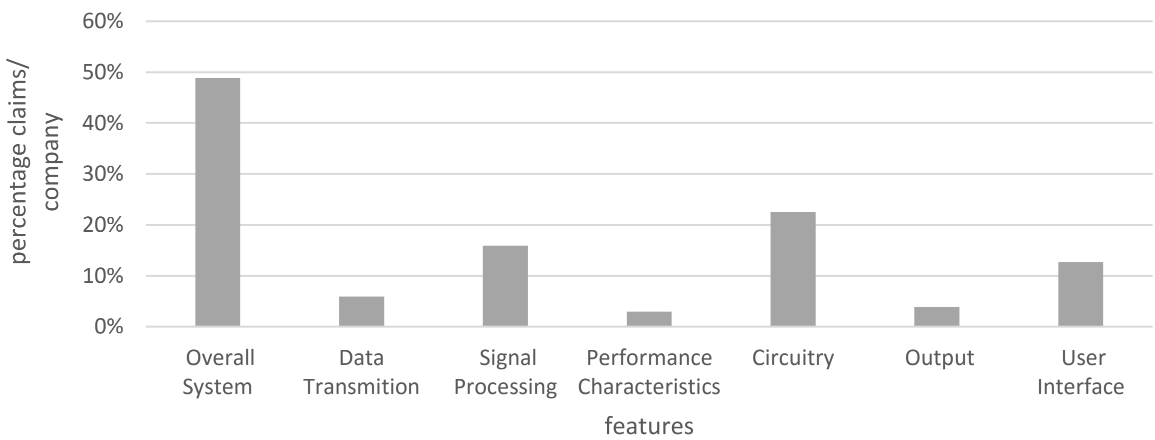
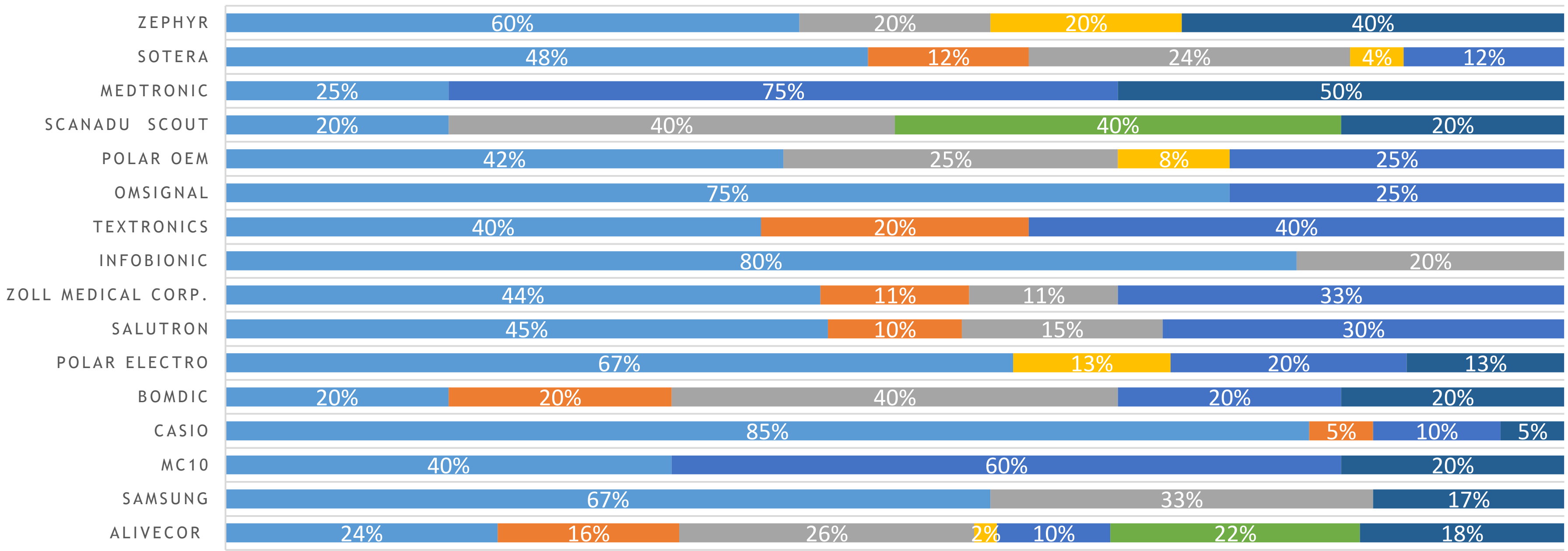


Figure 5-6 - Average of claimed product features per company. For each company, the percentage of each claimed feature was taking into consideration and then an average was calculated in order to understand the distribution per company.



	AliveCor	Samsung	MC10	Casio	bOMDIC	Polar Electro	Salutron	Zoll Medical Corp.	Infobionic	Textronics	OMSignal	Polar OEM	Scanadu Scout	Medtronic	Sotera	Zephyr
Overall System	24%	67%	40%	85%	20%	67%	45%	44%	80%	40%	75%	42%	20%	25%	48%	60%
Data Transmition	16%	0%	0%	5%	20%	0%	10%	11%	0%	20%	0%	0%	0%	0%	12%	0%
Signal Processing	26%	33%	0%	0%	40%	0%	15%	11%	20%	0%	0%	25%	40%	0%	24%	20%
Performance Characteristics	2%	0%	0%	0%	0%	13%	0%	0%	0%	0%	0%	8%	0%	0%	4%	20%
Circuitry	10%	0%	60%	10%	20%	20%	30%	33%	0%	40%	25%	25%	0%	75%	12%	0%
Output	22%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	40%	0%	0%	0%
User Interface	18%	17%	20%	5%	20%	13%	0%	0%	0%	0%	0%	0%	20%	50%	0%	40%

Figure 5-7 - Distribution of product features per company. Notice that Polar OEM also refers to one of the products of Polar Electro too.

6. DISCUSSION

6.1 WEARABLES AND PATENT TENDENCY

In this study, it is evidenced that the majority of the analyzed companies acting in the wearable industry has patents in their portfolio. Having focused on ECG, a widely used measure in healthcare, our study points towards the fact that the wearable medical devices are, in fact, in line with the medical devices industry, also protecting through patents the technological breakthroughs that will originate products [75]. However, why are companies patenting their inventions? According to Blind and colleagues [76], there are different approaches in order to justify this tendency and can be related to offensive or defensive strategies. Companies patent defensively in order to prevent other firms from patenting their inventions or even to block other market participants of using some sort of technologies. In the other hand, firms can patent offensively to prevent or block other firms from patenting inventions that are similar to their own inventions and which they intend to commercialize. If this is the case, the company will try to build a much broader patent wall when compared to a defensive patenting. This can prevent other firms from commercializing competing products [77].

In further analysis, we also show that the majority of patents are, in some way, related to wearable technologies. This result is expected since the company set was based on market studies and databases related to wearable technologies. Nevertheless, there is also a significant percentage of patents related with ECG. In order to obtain these insights, a keyword search was used. The effectiveness of this type of search is directly related to the selected keywords for retrieval [78]. In this stage, the keywords chosen were simple and broad enough in order to include every related patent. They were searched in every section of the patent text, contrarily to existing methodologies that strict their search to specific sections such as title, abstract or claims [78]. The reason for this is the fact that, in this part of the study, the goal was to obtain a general analysis and a preliminary selection of companies that operate in the specific area of wearable ECG technologies, so the search was not narrowed to any specific part of the patent. However, the retrieved results had to be further analyzed as some of them could not be particularly meaningful (e.g. the keyword was used only as a description of prior art to show an example of previous applications).

By combining the patent analysis with the product portfolio analysis, we show that around 60% of the considered patents are not currently incorporated into commercial products. As the companies analyzed are currently still in business (or were acquired by other companies), and as over 50% of the analyzed patents has a priority date from 2010 onwards, it is unlikely that these inventions were already implemented in a product that is now out of the market. Also, due to the regulatory process, product development cycles in medical devices are quite long. Therefore, these facts point out in the direction that patents that are not commercialized may yet not be in the market, as products that incorporate them may be under development. An analysis of these patents could have the potential to show what kind of ECG wearable products we will have in the market in the next few years.

It is interesting to note that 10 of the 15 analyzed companies have 510k approval, not necessarily related to an ECG product. This shows that the majority of companies is, in some way, acting in the medical device sector, since this approval is a regulatory path that allows the commercialization of this type of devices [79]. However, not every analyzed product can be considered a medical device, since they don't have any type of regulatory approval. Even so, this does not validate the exclusion of other devices (targeted for the fitness and wellbeing market), since they have the potential to be later approved as a medical device. By considering them, the scope of products we analyzed is wider and can produce more meaningful results. Additionally, a recent study by CBInsights [80],shows that the interest in WMDs is increasing when compared with devices targeted for the fitness market, so it will be expected that in the future these companies will seek regulatory approval in order to be able to perform in the medical industry also.

Further analyzing each individual company, the patent tendency is higher than 50%. There are some examples of companies (e.g. OMSignal) that have all the patents commercialized. Other companies have only the selected patents (with at least one of the defined CPC codes) commercialized (e.g. bOMDIC, Textronics). In this case, companies have more patents, but were not selected due to the search by classification (this is possible to see by analyzing the graphic of figure 5.6). It is also interesting to note that every company of the final set (of 15 companies) has at least one of the select patents exploited in one of its products. This fact evidence, once more, that companies are interested in protecting their own inventions, exercising either for offensive or defensive strategies.

Regarding the evolution over time, as stated before in the Results chapter, there is no evident trend. The patents that are previous to 1996 are already part of the public domain, since the 20 years of protection have already ended. Nevertheless, since 2004 there is always, at least one commercialized patent, with a peak in 2013. It is important to emphasize that this was the last full year analyzed, as patents filed in 2014 were public just up to October that year.

6.2 PATENT CLAIMS AND PRODUCT FEATURE ANALYSIS

By combining patent analysis and product portfolio analysis, it was also possible to understand what patent claims were actually related to technology in the product itself. While most claims appear to be related to the overall system, the results point out that there is still a patent vacuum regarding technologies that may impact product characteristics and user interfaces, thereby affecting product design. Since WMDs should be adapted to the human body and produce reliable results that help patients and physicians to take informed decisions [81], it is critical to consider technologies with impact on product design as a key point to ensure quality clinical results and patient comfort while using them. In turn, by understanding and filling this gap in the patent pool, companies have the potential to influence and accelerate the adoption of the wearable devices and their entry in the market. While Jee and Sohn [5] derive new product characteristics for wearable devices through a conjoint analysis, a market research technique, disregarding the possibility of actually implementing them in a real new product, the method proposed in this study uncovers product evolution areas that are potentially less patented and where there is still space for innovation.

The results obtained with this analysis can be interpreted in a number of different ways. On one hand, the high number of claims related to the overall system can be a sign that companies have a defensive strategy towards other companies. As previously referred, an offensive strategy can be characterized by patents with a larger patent portfolio [77]. The overall system is a characteristic of the product that can be quite generalist, therefore leading to patents with a broader scope.

Another interesting insight this study generated is that signal processing and circuitry are the following product characteristics with a higher percentage of assigned claims. As explained before (see 3. Literature Review), the major challenges in building a wearable ECG device rely on the development of compact, low power wearable sensors that are able to acquire, process and transmit the sensed signals. A high number of signal processing and circuitry claims can be a result of research and development efforts of technologies directed to such challenges.

The user interface is an important feature when designing a wearable device. In a world where people are overburdened with information and media channels, predictive, contextual and relevant information supersedes any functionality a device can offer making designing experiences a major challenge [82]. Furthermore, the user interface design of technology artifacts has been linked to usage behaviour and, when it comes to wearables, it appears that users tend to easily discontinue their use due to lack of interest [83]. Therefore, it would be reasonable to expect the incidence of this feature to be greater, however, it is only of 13% of the total set of independent claims. One possible interpretation for this would be that companies are not yet focused on user interfaces. However, user interfaces may be somehow harder to patent as many of them do not constitute, by themselves, patentable technologies. Therefore, the analysis of this issue resorting to our intellectual property rights, such as design protection.

Regarding data transmission, it would be also expected a higher incidence patent claims related to this feature, since the transmission of acquired signals is essential to the performance of the wearable device. However, this result could be due to the fact that only the independent claims were analyzed (the same can be applied to any of the previously mentioned features), disregarding information present in dependent claims.

Finally, there features presenting the lowest incidence in the analyzed claims were output and performance characteristics. Although it may be hard to explain this, it can be a result of the specificity of these two features. In fact, only two companies have output claims and the percentage associated with performance characteristics is extremely low for each company. Again, more specific claims are explored in the dependent claims. On the other hand, output and performance characteristics can also be an indirect result from technologies related to other features, such as signal processing, or circuitry.

Obviously, product feature-related claims with lower incidence could also mean that there is more space for innovation, as it was mentioned. Following this logic, there is a wider room for innovation in fields related to output and performance characteristics compared with signal processing, circuitry. It is interesting to note that when comparing the general patenting tendency with the tendency per company, the results are very similar. This can be the result of a similar strategy towards the protection of intellectual property or a convergence of companies' focus when addressing the development of their ECG devices.

6.3 COMBINING PATENT POOLS AND PRODUCT PORTFOLIO ANALYSIS – A NEW PATENT ANALYSIS APPROACH

As previously mentioned in the Literature Review, a typical patent analysis scenario involves different tasks, usually starting with task identification followed by the search of relevant patents, segmentation, information analysis, clustering of patents and, finally, visualization and interpretation [64]. Current methods for performing the different tasks are based on different techniques like text-mining, network analysis, citation analysis, index analysis, etc [43]. Additionally, current technology forecasting methods also rely mostly on conjoint analysis of patent pools and patent pool visualization methods, disregarding what is already in the market – the product portfolio. Therefore, this study introduces a new approach in order to combine patent pool analysis and product portfolio. The novelty of this method relies on crossing the obtained patents with the products of the companies that are being analyzed, uncovering areas for product evolution.

In order to produce reasonable and meaningful insights, first of all, the method needs a good initial set of companies. The number of patents that can potentially be obtained is dependent on the companies that explore the market segment in analysis and their magnitude. The preliminary analysis is not mandatory, however, as shown, it could help in better understand the industry dynamics and select the right companies for the study. The method used to select the patents of interest can also be different or even a combination of methods, depending on the sample's extent. In this case of application, a classification search was enough to produce meaningful insights about the wearables ECG industry. The CPC codes chosen were the ones that can be linked with wearable ECG devices.

Since the key of this method is crossing patent claims with product features, it is important to consult with experts in the area, in order to build a solid group of product characteristics. They should characterize the majority of products placed on the market under study in order to optimize the classification of each claim. This classification is subjective and some sort of validation is an advantage, which, in this study, was achieved through the use of one round of experts, which consists of part of the Delphi method, as referred in the Methodology.

One important limitation of our study is that we only looked into companies that were themselves the patent applicant, and therefore, we ignored the possibility of patent licensing among companies. Further analyzing the method and having in consideration what was mentioned previously it is evident that it has some drawbacks when compared with traditional methods, namely:

- It is dependent on the company being the applicant, leaving out situations where the applicant and the company commercializing the product – the licensee – is not the same [84]. This situation was addressed by checking the assignee of the patent, however, it could be troublesome in industries where licensing activity is important;
- It is mostly manual, making it more time consuming.
- an expert in the technical area under analysis is necessary, not only to define the product's characteristics, but also to classify correctly all claims;
- It can be subjective, depending on the expert that is using it;
- The initial company set has to be reliable, meaning that it needs to consist of companies that develop solutions to the industry in study;

- It only looks to the independent claims, leaving the dependent claims for analyzing.

Nevertheless, as shown before, this method is able to produce useful insights when applied to specific industries. By using it, it was possible to shed some light into what features are currently being patented, what is the focus of companies and what was the evolution over time.

7. CONCLUSIONS AND FUTURE IMPROVEMENTS

This study shows that the combination of patent analysis and product portfolio analysis is a complimentary method that can give insights about innovation in a specific sector. By applying it to the case of ECG wearable products, it was possible to understand if the existing patents are being applied to a product and the commercialization tendency through the years. By analyzing patent claims, it was possible to determine which the focus of companies when patenting a product is. We also uncover areas that can deliver short-term indications for new products. Therefore, one of our main conclusions is that companies in the wearable industry show a high tendency to patenting in the wearable technology market. For the studied companies that presented patents related with wearable ECG technologies, the majority of the analyzed patents are not yet incorporated in commercialized products, which can be a result of the regulatory process and the development cycle of wearable devices. As the majority of the analyzed claims are related to the overall system, it appears that there is less freedom to operate in features related to the overall system and more freedom to operate in features related to performance characteristics and outputs. In terms of patenting strategy, these companies appear to be following an offensive strategy – a high number of patents with broad scope.

Besides the contribution towards technological development in the wearable ECG area, this study also contributed to the analysis of patents from a market point of view. While the proposed method indeed allows insights on highly patented product features and opportunities towards technology development and product innovation, it has drawbacks, such as the time it takes, the dependence of the company being the applicant and subjectivity in the claims classification, as it is dependent on the expert panel. The generation of a thorough initial dataset of companies is also critical for the results.

Further studies could be performed in order to improve the method and the results obtained through it. For instance, the dependent claims could also be analyzed. This would allow a broader scope which could lead to more precise results. It would also be interesting to analyze the relationship between the company's dimension and its patent tendency, studying if there is any correlation between the number of patents and its position in the market. To better support and validate the presents theories, interviews to companies that work in the area could also be performed. This would help in understanding their strategy and focus, validating the assumptions about the obtained results. This method also disregards the value of the patent, giving the same weigh to every patent. In fact, each patent as a different impact, so it would be useful to study the technological and economic impact of both commercialized and not commercialized patents, in order to understand if there is any tendency that correlates value with patent exploitation. Last, the patent set of uncommercialized patents should also be analyzed in order to understand the type of products that might derive from the inventions they are protecting. This could have important implications for technological forecasting and competition analysis.

REFERENCES

[1] M. Davies, "Wearable Tech Can Extend Clinical Analytics," *Information Week Healthcare*, 2014. [Online]. Available: http://www.informationweek.com/healthcare/mobile-and-wireless/wearable-tech-can-extend-clinical-analytics/a/d-id/1297924. [Accessed: 04-Jan-2016].

[2] X. F. Teng, Y. T. Zhang, C. C. Y. Poon, and P. Bonato, "Wearable medical systems for p-Health.," *IEEE Rev. Biomed. Eng.*, vol. 1, pp. 62–74, 2008.

[3] J. Muhlsteff, O. Such, R. Schmidt, M. Perkuhn, H. Reiter, J. Lauter, J. Thijs, G. Musch, and M. Harris, "Wearable approach for continuous ECG--and activity patient-monitoring.," *Conf. Proc. IEEE Eng. Med. Biol. Soc.*, vol. 3, pp. 2184–7, 2004.

[4] M. S. Fernandes, J. H. Correia, and P. M. Mendes, "Electro-optic acquisition system for ECG wearable sensor applications," *Sensors Actuators, A Phys.*, vol. 203, pp. 316–323, 2013.

[5] S. J. Jee and S. Y. Sohn, "Patent network based conjoint analysis for wearable device," *Technol. Forecast. Soc. Change*, 2015.

[6] J. R. Cooper, "A multidimensional approach to the adoption of innovation," *Manag. Decis.*, vol. 36, no. 8, pp. 493–502, 1998.

[7] A. Mostafavi, D. M. Abraham, D. Delaurentis, and J. Sinfield, "Exploring the dimensions of systems of innovation analysis: A system of systems framework," *IEEE Syst. J.*, vol. 5, no. 2, pp. 256–265, 2011.

[8] H. Dou, V. Leveillé, S. Manullang, and J. Dou Jr, "Patent analysis for competitive technical intelligence and innovative thinking," *Data Sci. J.*, vol. 4, no. December, pp. 209–236, 2005.

[9] H. Grupp and U. Schmoch, "Patent statistics in the age of globalisation: new legal procedures, new analytical methods, new economic interpretation," *Res. Policy*, vol. 28, no. 4, pp. 377–396, 1999.

[10] WIPO, "Innovation and IP Protection," *Modul. III*, pp. 1–55, 2013.

[11] OECD, “Working Party on Environmental Information - Measuring environmental innovation using patent data: policy relevance,” 2011, no. December 2012, pp. 137–158.

[12] K. Lee and S. Lee, “Patterns of technological innovation and evolution in the energy sector: A patent-based approach,” *Energy Policy*, vol. 59, pp. 415–432, 2013.

[13] N. Sultan, “Reflective thoughts on the potential and challenges of wearable technology for healthcare provision and medical education,” *Int. J. Inf. Manage.*, vol. 35, no. 5, pp. 521–526, 2015.

[14] R. Almeida, “Characterization of Business Models in The Medical Devices Industry – the Case for Wearable Technologies,” 2015.

[15] P. Lukowicz, T. Kirstein, and G. Tröster, “Wearable systems for health care applications.,” *Methods Inf. Med.*, vol. 43, no. 3, pp. 232–8, 2004.

[16] S. Park, K. Chung, and S. Jayaraman, “Wearables,” *Wearable Sensors*, pp. 1–23, 2014.

[17] H. Yang, J. Yu, H. Zo, and M. Choi, “User acceptance of wearable devices: An extended perspective of perceived value,” *Telemat. Informatics*, vol. 33, no. 2, pp. 256–269, 2016.

[18] J. McCan and D. Bryson, *Smart Clothes and Wearable Technology*. Woodhead Publising in Textiles, 2009.

[19] M. Chan, D. Estève, J.-Y. Fourniols, C. Escriba, and E. Campo, “Smart wearable systems: Current status and future challenges,” *Artif. Intell. Med.*, vol. 56, no. 3, pp. 137–156, 2012.

[20] D. I. Fotiadis, C. Glaros, and A. Likas, “Wearable Medical Devices,” *Wiley Encycl. Biomed. Eng.*, no. APRIL 2006, 2006.

[21] K. Hung, Y. T. Zhang, and B. Tai, “Wearable medical devices for tele-home healthcare.,” *Conf. Proc. IEEE Eng. Med. Biol. Soc.*, vol. 7, pp. 5384–5387, 2004.

[22] G. Andreoni, M. Barbieri, and L. Piccini, “A Review of the Intellectual Property Rights in the Field of Wearable Sensors,” *Int. J. Comput. Res.*, vol. 18, no. 3, pp. 269–285, 2011.

[23] C. Spl, “Council Directive 93/42/EEC,” *SPL Certif.*, no. June 1993, pp. 1–60, 2007.

[24] Transparecy Market Reasearch, “Wearable Medical Devices Market (Heart Rate Monitors, Activity Monitors, ECG, Pulse Oximeters, EEG, EMG, Glucose/Insulin Management, Pain Management, Wearable Respiratory Therapy) - Global Industry Analysis, Size, Share, Growth, Trends and Forecast, 2013.” [Online]. Available: http://www.transparencymarketresearch.com/wearable-medical-devices.html.

[25] Y.-C. Li, J.-C. Yen, and M.-H. Hsu, “Embracing the era of wearable devices,” *J. Formos. Med. Assoc.*, pp. 5-6, 2015.

[26] M. S. Patel, D. a Asch, and K. G. Volpp, “Wearable Devices as Facilitators , Not Drivers , of Health Behavior Change,” *JAMA*, vol. 313, no. 5, pp. 459–460, 2015.

[27] S. Maulik and D. Ph, “WEARABLES AND INTERNET OF THINGS 2015,” 2015.

[28] Mordor Intelligence LLP, “Global Wearable Medical Device Market - Growth, Trends and Forecasts (2015-2020),” 2015. [Online]. Available: https://www.reportbuyer.com/product/3357066/global-wearable-medical-device-market-growth-trends-and-forecasts-2015-2020.html. [Accessed: 04-Jan-2016].

[29] PWC, “The wearable future - Consumer Intelligence Series.”

[30] R. Soumya, “Emerging Trends in the Wearable Healthcare market,” 2015. [Online]. Available: https://www.linkedin.com/pulse/emerging-trends-wearable-healthcare-market-soumya-rajan.

[31] K. L. Huberty, J. Faucette, J. Lu, J. Sole, E. Lui, and L. A. Carrier, “Wearable Devices: the ‘Internet of Things’ Becomes Personal,” *Morgan Stain.*, 2014.

[32] “Electrocardiogram (ECG or EKG).” [Online]. Available: http://www.heart.org/HEARTORG/Conditions/HeartAttack/SymptomsDiagnosisofHeartAttack/Electrocardiogram-ECG-or-EKG_UCM_309050_Article.jsp#.VzH7wvkrLIU.

[33] “Cardiovascular Consultants - Phisiology.” [Online]. Available: http://www.cardioconsult.com/Physiology/.

[34] M. Thaller, *The only EKG book you’ll ever need*, Fifth Edit. 2007.

[35] “Introduction to the ECG - ECG Waveforms.” [Online]. Available: http://www.cardionetics.com/ecg-waveforms#pwave.

[36] F. Miao, Y. Cheng, Y. He, Q. He, and Y. Li, “A wearable context-aware ECG monitoring system integrated with built-in kinematic sensors of the smartphone,” *Sensors (Switzerland)*, vol. 15, no. 5, pp. 11465–11484, 2015.

[37] C. J. Deepu, X. Y. Xu, X. D. Zou, L. B. Yao, and Y. Lian, “An ECG-on-chip for wearable cardiac monitoring devices,” *Proc. - 5th IEEE Int. Symp. Electron. Des. Test Appl. DELTA 2010*, pp. 225–228, 2010.

[38] S. Led, J. Fernández, and L. Serrano, “Design of a wearable device for ECG continuous monitoring using wireless technology,” *Annu. Int. Conf. IEEE Eng. Med. Biol. Soc.*, vol. 5, no. February, pp. 3318–21, 2004.

[39] M. S. Kheerthana and A. E. Manjunath, “A Survey on Wearable ECG Monitoring System using Wireless Transmission of Data,” vol. 4, no. 7, pp. 277–279, 2015.

[40] R. Geethika and A. E. Manjunath, “A Roadmap to Design and Analysis of Wearable ECG Monitoring System,” vol. 4, no. 7, pp. 274–276, 2015.

[41] C. Crandell, S. Tsuyuki, F. Bamarouf, T. Advisors, Y. Lu, and J. Sanchez, “Real-time Heart Monitoring and ECG Signal Processing,” 2015.

[42] Alivecor, “User Manual for Android,” no. October, pp. 1–69, 2014.

[43] S. Lee, B. Yoon, C. Lee, and J. Park, “Business planning based on technological capabilities: Patent analysis for technology-driven roadmapping,” *Technol. Forecast. Soc. Change*, vol. 76, no. 6, pp. 769–786, 2009.

[44] H. Zhou, P. G. Sandner, S. L. Martinelli, and J. H. Block, “Patents, trademarks, and their complementarity in venture capital funding,” *Technovation*, no. 2009, pp. 1–9, 2015.

[45] World Intellectual Property Organization, “WIPO Intellectual Property Handbook,” *WIPO Publ. No. 489*, p. 460, 2008.

[46] State Office of Industrial Property, “Regulation on Patent,” 2009.

[47] S. Lee, B. Yoon, and Y. Park, “An approach to discovering new technology opportunities: Keyword-based patent map approach,” *Technovation*, vol. 29, no. 6–7, pp. 481–497, 2009.

[48] Y. G. Kim, J. H. Suh, and S. C. Park, “Visualization of patent analysis for emerging technology,” *Expert Syst. Appl.*, vol. 34, no. 3, pp. 1804–1812, 2008.

[49] D. Hitchcock, *Patent Searching Made Easy: How to Do Patent Searches on the Internet & in the Librar*. 2013.

[50] OECD, “OECD Patent Statistics Manual,” 2009.

[51] T. Montecchi, D. Russo, and Y. Liu, “Advanced Engineering Informatics Searching in Cooperative Patent Classification : Comparison between keyword and concept-based search,” *Adv. Eng. Informatics*, vol. 27, no. 3, pp. 335–345, 2013.

[52] “Cooperative Patent Classification.” [Online]. Available: http://ep.espacenet.com/help?locale=en_EP&method=handleHelpTopic&topic=cpc. [Accessed: 05-Jan-2016].

[53] European Patent Office, “Coperative Patent Classification (CPC)Title.” [Online]. Available: https://www.epo.org/searching/essentials/classification/cpc.html. [Accessed: 05-Jan-2016].

[54] OECD, *Frascati Manual - Proposed standards practice for surveys on research and experimental development*. 2002.

[55] M. S. Clancy and G. Moschini, “Incentives for Innovation: Patents, Prizes, and Research Contracts,” *Appl. Econ. Perspect. Policy*, vol. 35, no. 2, pp. 206–241, 2013.

[56] M. Grimaldi, L. Cricelli, M. Di Giovanni, and F. Rogo, “The patent portfolio value analysis: A new framework to leverage patent information for strategic technology planning,” *Technol. Forecast. Soc. Change*, vol. 94, pp. 286–302, 2015.

[57] V. J. Thomas, S. Sharma, and S. K. Jain, “Using patents and publications to assess R&D efficiency in the states of the USA,” *World Pat. Inf.*, vol. 33, no. 1, pp. 4–10, 2011.

[58] J. Kim and S. Lee, “Patent databases for innovation studies: A comparative analysis of USPTO, EPO, JPO and KIPO,” *Technol. Forecast. Soc. Change*, vol. 92, pp. 332–345, 2015.

[59] M. Markatou and A. Vetsikas, “Innovation and Crisis: An Analysis of its Impact on the Greek Patenting Activity,” *Procedia - Soc. Behav. Sci.*, vol. 195, pp. 123–132, 2015.

[60] LexInnova, “Wearable Technology - Patent landscape analysis,” *Manual*.

[61] “Patent Search Strategies : Keywords or Classifications ?” [Online]. Available: http://patex.ca/pdf/publications/Patent Search Strategies.pdf.

[62] “Espacenet.” [Online]. Available: https://www.epo.org/searching/free/espacenet.html.

[63] “USPTO.” [Online]. Available: http://www.uspto.gov/.

[64] Y.-H. Tseng, C.-J. Lin, and Y.-I. Lin, “Text mining techniques for patent analysis,” *Inf. Process. Manag.*, vol. 43, no. 5, pp. 1216–1247, 2007.

[65] M. Moehlre, R. Isenmann, and R. Phaal, *Technology Roadmapping for Strategy and Innovation: Charting the Route to Success*. Springer Science & Business Media, 2013.

[66] B. Kang, “China Economic Review The innovation process of Huawei and ZTE : Patent data analysis,” *China Econ. Rev.*, vol. 36, pp. 378–393, 2014.

[67] CBInsights, “Beyond Mobile: 42 Wearables Startups Disrupting Fitness, Apparel, And Healthcare,” 2015. [Online]. Available: https://www.cbinsights.com/blog/wearable-computing-startups-list/?utm_source=CB+Insights+Newsletter&utm_campaign=ebf7a3b40c-EuropeanStartups_11_03_2015&utm_medium=email&utm_term=0_9dc0513989-ebf7a3b40c-87121469.

[68] SNSResearch, “The Wearable Technology Ecosystem: 2015 – 2030 - Opportunities, Challenges, Strategies, Industry Verticals and Forecasts,” 2015.

[69] IDTechEx, “Wearable Sensors 2016-2026: Market Forecasts, Technologies, Players,” 2016.

[70] Kalorama Information, “The Market for Wearable Devices,” 2015.

[71] “Google Patents.” [Online]. Available: https://www.google.pt/?tbm=pts&gws_rd=cr,ssl&ei=04ZJV9brJomsU8nuneAJ.

[72] “Espacenet.” [Online]. Available: http://worldwide.espacenet.com/advancedSearch?locale=en_EP.

[73] “Espacenet - Claims.” [Online]. Available: https://worldwide.espacenet.com/help?locale=en_EP&method=handleHelpTopic&topic=claims.

[74] V. Modrak and P. Bosun, “Using the Delphi method in forecasting tourism activity,” *Int. Lett. Soc. Humanist. …*, vol. 25, pp. 66–72, 2014.

[75] A. K. Chatterji, “Spawned with a silver spoon? Entrepreneurial performance and innovation in the medical device industry,” *Strateg. Manag. J.*, vol. 30, no. 2, pp. 185–206, 2009.

[76] K. Blind, K. Cremers, and E. Mueller, “The influence of strategic patenting on companies’ patent portfolios,” *Res. Policy*, vol. 38, no. 2, pp. 428–436, 2009.

[77] A. Arundel and P. Patel, “European Trend Chart on Innovation Strategic patenting,” *Backgr. Rep. Trend Chart Policy Benchmarking Work. New Trends IPR Policy*, no. June, pp. 1–19, 2003.

[78] Z. Xie and K. Miyazaki, “Evaluating the effectiveness of keyword search strategy for patent identification,” *World Pat. Inf.*, vol. 35, no. 1, pp. 20–30, 2013.

[79] D. M. Zuckerman, P. Brown, and S. E. Nissen, “Medical device recalls and the FDA approval process,” *Arch Intern Med*, vol. 171, no. 11, pp. 1006–11, 2011.

[80] CBInsights, “Beyond the Hype Cycle: Quantifying Media Attention to Predict Technology Trends,” 2016.

[81] C. Crean, C. Mcgeough, and R. O’Kennedy, “Wearable biosensors for medical applications,” *Biosens. Med. Appl.*, pp. 301–330, 2012.

[82] “The design challenge of wearables.” [Online]. Available: http://www.theguardian.com/media-network/media-network-blog/2014/apr/16/wearable-technology-design-interface.

[83] V. Dibia, “An affective, normative and functional approach to designing user experiences for wearables,” pp. 1–12.

[84] R. Feldman and M. A. Lemley, “Do patent licensing demands mean innovation?,” *Iowa Law Rev.*, vol. 101, no. 1, pp. 137–189, 2015.

[85] "Students Nurse Diaries." [Online]. Available: https://studentnursediaries.files.wordpress.com/2011/06/normalecg2.png.

[86] "Google Patents." [Online]. Available: https://patents.google.com/?q=ecg,EKG&q=wearable&assignee=alivecor.

8. APPENDICES

8.1 COMPANIES LIST

Empresa	ECG?	Patents?	KW ECG ?	KW wearable?	Both?
270 Vision	No	No	No	No	No
3L Labs	No	No	No	No	No
3rings	No	Yes	No	No	No
4DForce	No	No	No	No	No
4iii Innovations	No	No	No	No	No
9Solutions	No	Yes	No	No	No
Abbot Laboratories	No	Yes	No	No	No
Abbot Pathology	**Yes**	Yes	No	No	No
AcousticSheep	No	No	No	No	No
Active Mind Technology	No	Yes	No	No	No
AdhereTech	No	Yes	No	No	No
Adidas	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
AgaMatrix	No	Yes	No	No	No
Aira.IO	No	No	No	No	No
AirType	No	No	No	No	No
AliveCor	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
Amazon	No	Yes	No	Yes	No
Ambit Networks	No	No	No	No	No
AMD (Advanced Micro Devices)	No	Yes	Yes	Yes	No
Amiigo	No	Yes	No	Yes	No
Amulyte	No	No	No	No	No
Animas	No	Yes	No	Yes	No
Apple	No	Yes	Yes	Yes	Yes
APX Labs	No	Yes	No	Yes	No
ARA (Applied Research Associates)	No	Yes	No	Yes	No
Archos	No	Yes	No	No	No
ARM Holdings	No	No	No	No	No
Asahi Kasei Group	**Yes**	**Yes**	No	No	No

ASUS (ASUSTeK Computer)	**No**	**Yes**	No	No	No
ASX	No	No	No	No	Nºao
AT&T Mobility	No	Yes	No	Yes	No
Atellani	No	No	No	No	No
Atheer Labs	No	No	No	No	No
Athos Works	No	Yes	Yes	Yes	Yes
Atlas Wearables	No	Yes	Yes	Yes	Yes
Augmedix	No	Yes	No	Yes	No
Avegant	No	Yes	No	Yes	No
Avery Dennison	**Yes**	**Yes**	**Yes**	**Yes**	**No**
AVG	No	Yes	No	No	No
Awarepoint	No	Yes	Yes	No	No
BabyBe	No	No	No	No	No
BAE Systems	No	Yes	No	Yes	No
Baidu	No	Yes	No	Yes	No
Barclays	No	Yes	No	No	No
Basis Science	No	Yes	Yes	Yes	Yes
BeBop Sensors	No	Yes	No	Yes	No
Beddit	No	**Yes**	**No**	**Yes**	**No**
Behavioral Technology Group	No	No	No	No	No
BI					
BIA Sport	Nao	No	No	No	No
Bionym	**Yes**	**Yes**	Yes	Yes	Yes
Biosensics	No	Yes	No	No	No
BioSerenity	No	No	No	No	No
BIT (Blue Infusion Technologies)	No	Yes	No	No	No
Bitbanger Labs	No	No	No	No	No
BL Healthcare	No	No	No	No	No
Blocks Wearables	**Yes**	No	No	No	No
Bluetooth Special Interest Group	No	No	No	No	No
BodyMedia	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
bOMDIC	**Yes**	**Yes**	Yes	Yes	Yes
Boston Scientific Corporation	**Yes**	**Yes**	**Yes**	**Yes**	**No**
BRAGI	No	Yes	No	No	No
Breitling	No	Yes	No	No	No
Brilliantservice	No	Yes	No	Yes	No
Broadcom	No	Yes	Yes	Yes	Yes
Brother Industries	No	Yes	No	-	No
Brunel University	No	Yes	No	No	No
BSX Atheletics	No	No	No	No	No
BSX Insight	No	No	No	No	No
BTS Bioengineering	No	No	No	No	No
Buhel	No	Yes	No	No	No
Cambridge Temperature Concepts	No	Yes	No	Yes	No
Carre Technologies	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**

Casio	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
Catapult Sports	No	No	No	No	No
CETEMMSA	No	Yes	No	No	No
Chrono Therapeutics	No	Yes	No	No	No
Cisco Systems	No	**Yes**	No	No	No
Citizen	No	Yes	Yes	Yes	No
Cityzen Sciences	No	No	No	No	No
Clothing+	No	Yes	Yes	Yes	Yes
Codoon	No	No	No	No	No
CommandWear	No	No	No	No	No
CompeGPS	No	No	No	No	No
Compumed Inc.	**Yes**	Yes	No	No	No
Connect America	No	Yes	No	No	No
ConnecteDevice	No	Yes	No	No	No
ConnectedHealth	No	No	No	No	No
Control VR	No	Yes	No	No	No
Cool Shirt Systems	No	No	No	No	No
Covidien	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
Creaholic	No	Yes	No	No	No
Creoir	No	Yes	No	No	No
CSR	No	Yes	No	Yes	No
Cue	No				
Cuff	No	Yes	No	Yes	No
Cyberdyne	No	Yes	Yes	Yes	No
DAQRI	No	Yes	No	Yes	No
DARPA	No	No	No	No	No
Dell	No	**Yes**	**Yes**	**Yes**	**No**
Diesel	No	Yes	No	No	No
DK Tek Innovations	No	No	No	No	No
DKNY	No	No	No	No	No
Doppler Labs	No	Yes	No	No	No
DorsaVi	No	Yes	No	No	No
Dreamtrap Commercials	No	No	-	-	-
Dubai Police	No	No	No	No	No
Durex	No	Yes	No	No	No
E Ink Holdings	No	Yes	No	No	No
EarlySense	No	Yes	Yes	Yes	Yes
EB Sport Group	No	No	No	No	No
EdanSafe	No	Yes	No	No	No
Ekso Bionics	No	Yes	No	-	No
Electric Foxy	No	No	No	No	No
Electrozyme	No	Yes	No	Yes	No
Emotiv Systems	No	Yes	Yes	No	No
Enjoy S.R.L	No	No	No	No	No
Epson (Seiko Epson Corporation)	No	Yes	Yes	Yes	No

EuroTech	No	Yes	No	Yes	No
Evena Medical	No	Yes	Yes	Yes	Yes
Everfind	No	No	No	No	No
Evermind	No	Yes	No	No	No
Everywear Games	No	No	No	No	No
Exelis	No	Yes	No	Yes	No
Eyenetra	No	No	No	No	No
EyeTap	No	No	No	No	No
Facebook	No	Yes	No	Yes	No
FashionTEQ	No	Yes	No	Yes	No
Fat Shark	No	No	No	No	No
Fatigue Science	No	Yes	Yes	Yes	Yes
FDA (U.S. Food and Drug Administration)	No	No	No	No	No
Filip Technologies	No	Yes	No	Yes	No
Finis	No	Yes	No	No	No
FitBark	No	No	No	No	No
Fitbit	No	Yes	Yes	Yes	Yes
Fitbug	No	**Yes**	**No**	**Yes**	**No**
FitLinxx	**Yes**	**Yes**	Yes	Yes	Yes
Flextronics	No	Yes	No	Yes	No
Flyfit	No	No	No	No	No
Force Impact Technologies	No	No	No	No	No
Fossil	No	Yes	No	Yes	No
Foxtel	No	No	No	No	No
Free Wavz	No	No	No	No	No
Freescale Semiconductor	No	Yes	No	Yes	No
Fruit Street	No	No	No	No	No
Fujitsu	**No**	**Yes**	**Yes**	**Yes**	**Yes**
Garmin	**No**	**Yes**	**Yes**	**Yes**	**No**
GE Healthcare	**Yes**	**Yes**	**Yes**	**No**	**No**
GEAK	No	No	No	No	No
Gemalto	No	Yes	No	Yes	No
General Dynamics Corporation	No	Yes	-	No	No
General Dynamics Mission Systems	No	No	No	No	No
GEO Group	No	Yes	No	No	No
Geopalz	No	No	No	No	No
Georgia Institute of Technology	No	Yes	No	No	No
GestureLogic	No	Yes	No	Yes	No
Ginger.io	No	Yes	No	Yes	No
Given Imaging	No	Yes	No	Yes	No
GlassUp	No	Yes	Yes	Yes	No
Glofaster	No	No	No	No	No
GlucoVista	No	Yes	No	Yes	No
GN Netcom	No	Yes	No	Yes	No
GN Store Nord	No	Yes	No	-	No

Google	Yes	Yes	Yes	Yes	No
GoPro	No	Yes	No	No	No
GOQii	No	No	No	No	No
Gucci	No	Yes	No	No	No
Guess	No	Yes	No	No	No
Halo Neuroscience	No	No	No	No	No
HealBe	No	Yes	No	No	No
Hello	No	Yes	Yes	Yes	Yes
HereO	No	Yes	No	No	No
Hollywog	No	Yes	No	No	No
Honeywell International	No	Yes	Yes	Yes	No
House of Horology	No	No	No	No	No
Hovding	No	Yes	No	Yes	No
HP	Yes	Yes	Yes	Yes	No
HTC	No	**Yes**	**Yes**	**Yes**	**Yes**
Huami Technology	No	Yes	No	No	No
Huawei	No	Yes	Yes	Yes	Yes
i.am+	No	Yes	No	Yes	No
i'm SpA	No	No	No	No	No
i4C Innovations	No	Yes	Yes	Yes	No
IAMAS	No	No	No	No	No
ICEdot	No	No	No	No	No
ICON Health and Fitness	No	Yes	Yes	No	No
IDENTEC GROUP	No	Yes	No	No	No
iHealth Lab	No	No	No	No	No
iLOC Technologies	No	Yes	No	Yes	No
Imagination Technologies	No	Yes	No	No	No
Imec	Yes	Yes	Yes	Yes	Yes
Immerz	No	Yes	No	No	No
Ineda Systems	No	Yes	No	Yes	No
InfinitEye	No	No	No	No	No
Infobionic	Yes	Yes	Yes	Yes	Yes
Innovega	No	Yes	No	No	No
Instabeat	No	No	No	No	No
Intel Corporation	No	Yes	Yes	Yes	Yes
InteraXon	No	Yes	No	Yes	No
InteraXon (Muse)	No	No	No	No	No
InvenSense	No	Yes	Yes	Yes	Yes
Iotera	No	Yes	No	No	No
iRhythm	Yes	Yes	Yes	Yes	Yes
Iron Will Innovations	No	Yes	No	Yes	No
ITAMCO	No	No	No	No	No
ITT Corporation	No	Yes	No	No	No
Jabra	No	Yes	No	Yes	No
Jan Medical	No	Yes	Yes	No	No

Jawbone	No	Yes	No	No	No
Jaybird	No	Yes	No	Yes	No
Johnson & Johnson	No	Yes	No	Yes	No
Johnson & Johnson Innovations	No	No	No	No	No
Kairos Watches	No	Yes	No	Yes	No
Kapture	No	No	No	No	No
Ki Performance	No	No	No	No	No
Kinsa	Yes	Yes	No	Yes	No
Kiwi Wearable Technologies	No	No	No	No	No
KMS Solutions	No	No	No	No	No
KoruLab	No	Yes	No	No	No
Kreyos	No	No	No	No	No
Kronoz	No	No	No	No	No
L-3 Communications	No	Yes	No	Yes	No
L-3 Mobile-Vision	No	Yes	No	Yes	No
Lark Technologies	No	Yes	Yes	Yes	Yes
Laster Technologies	No	No	No	No	No
LeapFrog Enterprises	No	Yes	No	No	No
Lechal	No	No	No	No	No
Ledong Information Technology	No	No	No	No	No
Lemonade Lab	No	No	No	No	No
Lenovo	No	Yes	No	Yes	No
LG Electronics	No	Yes	Yes	Yes	Yes
LifeBEAM	No	Yes	No	No	No
LifeLogger Technologies Corporation	No	No	No	No	No
Limmex	No	Yes	No	Yes	No
Liquid Image	No	Yes	No	No	No
Little Labs	No	No	No	No	No
Lockheed Martin	No	Yes	Yes	Yes	No
LogBar	No	Yes	No	Yes	No
LOSTnFOUND	N	No	No	No	No
Loughborough University	No	Yes	No	Yes	No
Lumafit	No	No	No	No	No
Lumo BodyTech	No	Yes	No	No	No
Lumus	No	Yes	No	Yes	No
Luxottica	No	Yes	No	Yes	No
Mad Apparel	No	Yes	Yes	Yes	Yes
Magellan (MiTAC Digital Corporation)	No	Yes	No	No	No
Magic Leap	No	Yes	No	Yes	No
Martian Watches	No	No	No	No	No
Matilde					
MC10	Yes	Yes	Yes	Yes	Yes
McLear	No	Yes	No	Yes	No
mCube	No	Yes	No	No	No
MediaTek	No	Yes	Yes	Yes	No

Medtronic	Yes	Yes	Yes	Yes	Yes
Melon	No	No	No	No	No
Memi	No	Yes	No	Yes	No
META	No	Yes	No	Yes	No
Meta Watch	No	Yes	No	Yes	No
Microsoft	No	Yes	Yes	Yes	Yes
Mindray Medical International Limited	Yes	Yes	Yes	Yes	Yes
MindStream	No	Yes	No	No	No
Mio Global	Yes	No	No	No	No
Misfit Wearables	No	Yes	No	No	No
MiTAC International	No	Yes	No	Yes	No
Moff	No	Yes	No	No	No
MonDevices	No	Yes	No	No	No
Moov	No	Yes	No	No	No
Mortara Instrument, Inc.	Yes	Yes	Yes	No	No
Moticon	No	Yes	No	No	No
Motion Fitness	No	No	Ñão	No	No
Motion Metrics International Corporation	No	Yes	No	No	No
Motiv	No	Yes	No	Yes	No
Motorola Mobility	No	Yes	Yes	Yes	Yes
Motorola Solutions	No	Yes	Yes	Yes	Yes
Movable	No	No	No	No	No
Mozilla Corporation	No	No	No	No	No
Mutalink	No	No	No	No	No
Mutewatch	No	No	No	No	No
Myontec	No	Yes	No	No	No
Narrative	No	Yes	No	Yes	No
Neptune	No	Yes	No	Yes	No
Netatmo	No	Yes	No	No	No
NeuroPro	No	Yes	No	No	No
Neurosky	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
Neurovigil	No	Yes	Yes	No	No
New Balance	Yes	Yes	No	Yes	No
Nihon Kohden Corporation	Yes	Yes	Yes	Yes	Yes
Nike	No	Yes	Yes	Yes	Yes
Nintendo	No	Yes	Yes	Yes	Yes
Nissan	No	Yes	Yes	Yes	Yes
Nixie Labs	No	Yes	No	Yes	No
Nixon	No	Yes	No	Yes	No
Nod	No	Yes	No	Yes	No
Nokia	No	Yes	Yes	Yes	Yes
Notch Interfaces	No	No	No	No	No
Novasom	No	No	No	No	No
NTT DoCoMo	No	Yes	Yes	Yes	Yes
Nuance	No	Yes	Yes	Yes	No

Nuubo	Yes	No	No	No	No
NVIDIA	Yes	Yes	No	Yes	No
NZN Labs	No	No	No	No	No
Obaa	No	No	No	No	No
Oculus VR	No	Yes	No	No	No
ODG (Osterhout Design Group)	No	Yes	No	Yes	No
Ohmatex	No	No	No	No	No
Olio Devices	No	Yes	No	Yes	No
Olive Labs					
Omate	No	No	No	No	No
Omega	No	Yes	No	Yes	No
OMG Life	No	No	No	No	No
Omron	No	Yes	Yes	Yes	Yes
OMsignal	Yes	Yes	Yes	Yes	Yes
Opening Ceremony	No	Yes	No	Yes	No
Optalert	No	Yes	No	No	No
Optinvent	No	Yes	No	No	No
Orange	No	Yes	Yes	Yes	Yes
OrCam Technologies	No	Yes	No	Yes	No
OriginGPS	No	Yes	No	No	No
Orion Labs (OnBeep)	No	No	No	No	No
Orpyx Medical Technologies	No	Yes	Yes	No	No
O-Synce	No	No	No	No	No
Owlet Baby Care	No	No	No	No	No
Palomar Health	No	No	No	No	No
Panasonic	No	Yes	Yes	Yes	Yes
Paris Miki Holdings	No	Yes	No	No	No
Parvus	No	Yes	No	No	No
Pebble Technology	No	Yes	No	Yes	No
Pepsi	No	Yes	No	No	No
Perceptive Devices	No	Yes	No	Yes	No
Performance Sports Group	No	No	No	No	No
Perpetua Power Source Technologies	No	Yes	Yes	Yes	Yes
PFO Tech	No	No	No	No	No
Philips	Yes	Yes	Yes	Yes	Yes
PHTL (PH Technical Labs)	No	Yes	No	No	No
Phyode	No	No	No	No	No
Pivothead	No	No	No	No	No
Pixie Scientific	No	Yes	No	Yes	No
Plantronics	No	Yes	No	Yes	No
Playtabase	No	Yes	No	Yes	No
PNI Sensor Corporation	No	Yes	No	No	No
Polar Electro	Yes	Yes	Yes	Yes	Yes
Polyera	No	Yes	No	Yes	No
Pragmasystems	No	No	No	No	No

Preventice	Yes	No	No	No	No
Pristine	No				
Proteus Digital Health	No	Yes	Yes	Yes	Yes
PST Sensors	No	Yes	No	No	No
PUSH Design Solutions	No	Yes	No	No	No
Qardio	Yes	Yes	Yes	Yes	Yes
Qualcomm	Yes*	Yes	Yes	Yes	Yes
Quanttus	No	Yes	No	Yes	No
Ralph Lauren Corporation	No	Yes	No	No	No
Raytheon	No	Yes	Yes	Yes	Yes
Razer	No	Yes	No	Yes	No
Recon Instruments	No	Yes	No	Yes	No
Reebok International	No	Yes	Yes	Yes	Yes
Rest Devices	No	Yes	No	No	No
Revolutionary Tracker	No	No	No	No	No
RHLvision Technologies	No	No	No	No	No
Ringblingz	No	No	No	No	No
Ringly	No	Yes	No	No	No
Royal Philips Healthcare	Yes	No	No	No	No
RSL Steeper Group	No	Yes	No	No	No
Rufus Labs	No	No	No	No	No
S3 ID	No	Yes	No	No	No
Salesforce.com	No	Yes	No	Yes	No
Salutron	Yes	Yes	Yes	Yes	Yes
Samsung Electronics	Yes	Yes	Yes	Yes	Yes
Sano Intelligence	No	Yes	No	No	No
Sarvint Technologies	No	No	No	No	No
Scanadu	Yes	Yes	Yes	Yes	Yes
Schiller AG	Yes	Yes	Yes	No	No
Secret Labs	No	No	No	No	No
Seiko	No	Yes	Yes	Yes	Yes
SenseCore	Yes	No	No	No	No
Sensegiz Technologies	No	Yes	No	No	No
Senseonics	No	Yes	Yes	Yes	No
Sensible Baby	No	No	No	No	No
Senso Solutions	No	No	No	No	No
Sensoplex	No	No	No	No	No
Sensoria	No	Yes	Yes	Yes	Yes
Sentimoto	No	No	No	No	No
Seraphim Sense	No	Yes	No	Yes	No
Shanda Group	No	No	No	No	No
Shimmer	Yes	Yes	No	No	No
ShotTracker	No	Yes	No	No	No
Sigmo	No	No	No	No	No
Silent Alert Monitor	No	Yes	No	Yes	No

Yesplifeye	No	No	No	No	No
SITA	No	No	No	No	No
Skully Systems	No	No	No	No	No
Smart Device (SmartQ)	No	Yes	No	No	No
Smarty Destination Technology		No	No	No	No
Smarty Ring	No	No	No	No	No
SMI (SensoMotoric Instruments)	-	Yes	Yes	No	No
SMS Audio	No	Yes	No	No	No
Snaptracs	No	No	No	No	No
Somaxis	Yes	Yes	Yes	Yes	Yes
Sonitus Medical	No	Yes	Yes	Yes	Yes
Sonostar	No	No	No	No	No
Sony Corporation	No	Yes	Yes	Yes	Yes
Sony Mobile Communications	No	Yes	Yes	Yes	No
Sotera Wireless	Yes	Yes	Yes	Yes	Yes
Soundbrenner	No	No	No	No	No
Spacelabs Healthcare Inc.	Yes	No	No	No	No
SparkPeople	No	No	No	No	No
Spire	No	Yes	No	No	No
Sports Beat	No	No	No	No	No
SpotNSave	No	No	No	No	No
Spree Wearables	No	No	No	No	No
Sproutling	No	Yes	No	Yes	No
Sqord	No	Yes	No	No	No
Stalker Radar (Applied Concepts)	No	Yes	No	No	No
STATSports	No	No	No	No	No
STMicroelectronics	No	Yes	Yes	Yes	Yes
Stretchsense	No	Yes	No	Yes	No
Striiv	No	Yes	No	No	No
SunFriend Corporation	No	Yes	No	Yes	No
Sunsprite	No	No	No	No	No
Survios	No	No	No	No	No
Suunto	No	Yes	Yes	Yes	Yes
sWaP					
Swatch Group	No	Yes	No	Yes	No
T.Ware	No	Yes	No	No	No
Tag Heuer	No	Yes	No	No	No
Tarsier	No	No	No	No	No
TASER International	No	Yes	Yes	No	Yes
TCL Communication	No	Yes	Yes	Yes	Yes
Technical Illusions	No	Yes	No	No	No
Teletracking	No	Yes	Yes	No	No
Textronics	Yes	Yes	Yes	Yes	Yes
Thalmic Labs	No	Yes	Yes	Yes	Yes
The Walt Disney Company	No	Yes	No	Yes	No

Theatro	No	Yes	No	No	No
Thync	No	Yes	Yes	Yes	Yes
TI (Texas Instruments)	Yes	Yes	Yes	Yes	Yes
Timex Group	No	Yes	Yes	Yes	Yes
Tissot	No	No	No	No	No
TLink Golf	No	No	No	No	No
TN Games	No	No	No	No	No
Tobii Technology	No	Yes	No	Yes	No
Tomoon Technology	No	No	No	No	No
TomTom	No	Yes	No	Yes	No
Tory Burch	No	No	No	No	No
Touch Bionics	No	Yes	No	No	No
TrackingPoint	No	Yes	No	No	No
TuringSense	No	No	No	No	No
Two Tin Cans	No	No	No	No	No
U.S. Department of Defense	No	No	No	No	No
U-blox	No	Yes	No	No	No
Under Armour	No	Yes	Yes	Yes	No
Universities of Glasgow	No	Yes	Yes	Yes	Yes
University of Leeds	No	Yes	Yes	No	No
University of Reading	No	Yes	No	Yes	No
University of Strathclyde	-	Yes	No	Yes	No
Uno					
Valencell	No	Yes	Yes	Yes	Yes
Validic (Motivation Science)	No	No	No	No	No
Vancive Medical Technologies	No	Yes	No	No	No
Vergence Labs	No	No	No	No	No
Victoria's Secret	No	Yes	No	No	No
Vigo	No	No	No	No	No
Virgin Atlantic	No	Yes	No	No	No
VitalConnect	Yes	No	No	No	No
Vivalnk	Yes	Yes	Yes	Yes	No
Voluntis	No	Yes	Yes	No	No
VSN Mobil	No	No	No	No	No
Vuzix	No	Yes	No	Yes	No
Wahoo Fitness	No	Yes	No	Yes	No
Wather Enterprises	-	No	No	No	No
We:eX (Wearable Experiments)	No	Yes	No	No	No
Wearable Intelligence	No	Yes	No	Yes	No
Weartrons Labs	No	No	No	No	No
Welch Allyn	Yes	Yes	Yes	Yes	Yes
Wellograph	No	No	No	No	No
Whistle	No	Yes	No	Yes	No
Whoop	No	Yes	Yes	Yes	Yes
Wirecard	No	Yes	No	No	No

Withings	No	Yes	Yes	No	No
WTS (Wonder Technology Solutions)	No	No	No	No	No
X-Doria (Doria International)	No	No	No	No	No
Xensr	No	No	No	No	No
Xiaomi	No	Yes	No	Yes	No
XO Eye Technologies	No	No	No	No	No
XOWi	No	No	No	No	No
Xybermind	No	Yes	No	No	No
Ybrain	No	Yes	No	Yes	No
Yingqu Technology	No	No	No	No	No
Zackees	No	Yes	No	Yes	No
Zeiss (Carl Zeiss)	No	Yes	Yes	Yes	No
Zephyr Technology	Yes	Yes	Yes	Yes	Yes
Zepp Labs	No	Yes	No	No	No
Zinc Software	No	Yes	Yes	No	No
Zoll Medical Corporation	Yes	Yes	Yes	Yes	Yes
ZTE	No	Yes	Yes	Yes	Yes

8.2 Patent List

Empresa	Title
AliveCor	METHODS AND SYSTEMS FOR CARDIAC MONITORING WITH MOBILE DEVICES AND ACCESSORIES
AliveCor	METHODS AND SYSTEMS FOR ARRHYTHMIA TRACKING AND SCORING
AliveCor	SMARTPHONE AND ECG DEVICE MICROBIAL SHIELD
AliveCor	UNIVERSAL ECG ELECTRODE MODULE FOR SMARTPHONE
AliveCor	UNIVERSAL ECG ELECTRODE MODULE FOR SMARTPHONE
AliveCor	Apparatus for Coupling to Computing Devices and Measuring Physiological Data
AliveCor	TWO ELECTRODE APPARATUS AND METHODS FOR TWELVE LEAD ECG
AliveCor	TWO ELECTRODE APPARATUS AND METHODS FOR TWELVE LEAD ECG
AliveCor	CARDIAC PERFORMANCE MONITORING SYSTEM FOR USE WITH MOBILE COMMUNICATIONS DEVICES
AliveCor	ELECTROCARDIOGRAM SIGNAL DETECTION
AliveCor	ULTRASONIC TRANSMISSION OF SIGNALS
AliveCor	Personal monitoring device, ECG device and smart phone protection box
AliveCor	WIRELESS, ULTRASONIC PERSONAL HEALTH MONITORING SYSTEM
AliveCor	HEART MONITORING DEVICE USABLE WITH A SMARTPHONE OR COMPUTER
bOMDIC	STAMINA MONITORING METHOD AND DEVICE
Casio	MOTION INFORMATION DETECTION APPARATUS, MOTION INFORMATION DETECTION METHOD (...)
Casio	CARDIOTACHOMETER AND ITS ATTACHMENT METHOD
Casio	CARDIOTACHOMETRY DEVICE AND OPERATION METHOD OF THE SAME
Casio	Measurement of electrocardiographic wave and sphygmus
Casio	Exercise level of difficulty data output apparatus
Medtronic	SYSTEM AND METHODS FOR WIRELESS BODY FLUID MONITORING
Medtronic	Wireless cardiac pulsatility sensing

Medtronic	Skin-mounted electrodes with nano spikes
Medtronic	SYSTEM FOR DYNAMIC REMOTE NETWORKING WITH IMPLANTABLE MEDICAL DEVICES
Neurosky	Mobile cardiac health monitoring
OMSignal	TEXTILE BLANK WITH SEAMLESS KNITTED ELECTRODE SYSTEM
Polar Electro	Transfer of Measurement Data Related to Physical Exercise
Polar Electro	TRANSFER OF MEASUREMENT DATA RELATED TO PHYSICAL EXERCISE
Polar Electro	SENSOR SYSTEM, GARMENT AND HEART RATE MONITOR
Polar Electro	Screen
Polar Electro	Wrist-worn device
Polar Electro	Method of monitoring human relaxation level, and user-operated heart rate monitor
Polar Electro	Method and device for measuring heart rate, and method for manufacturing the device
Polar Electro	Calibration of performance monitor
Polar Electro	Method and apparatus for measuring heart rate
Polar Electro	Method of performing operating settings in heart rate measurement arrangemen (...)
Polar Electro	Method and arrangement for heartbeat detection
Polar Electro	Electrode belt of heart rate monitor
Polar Electro	Connecting arrangement at heart rate monitor and electrode belt
Polar Electro	Heart rate monitor, method and computer software product
Polar Electro	Integral heart rate monitoring garment
Polar Electro	Electrode structure integrated into a belt for measuring a person's heart rate has a contact surface (...)
Sotera Wireless	BODY-WORN MONITOR FOR MEASURING RESPIRATORY RATE
Sotera Wireless	SYSTEM FOR MEASURING VITAL SIGNS USING BILATERAL PULSE TRANSIT TIME
Sotera Wireless	BODY-WORN VITAL SIGN MONITOR
Sotera Wireless	OPTICAL SENSORS FOR USE IN VITAL SIGN MONITORING
Sotera Wireless	BODY-WORN PULSE OXIMETER
Sotera Wireless	SYSTEM THAT MONITORS PATIENT MOTION AND VITAL SIGNS
Sotera Wireless	VITAL SIGN MONITORING SYSTEMS
Sotera Wireless	HAND-HELD VITAL SIGNS MONITOR
Sotera Wireless	BODY-WORN SENSOR FEATURING A LOW-POWER PROCESSOR AND (...)
Sotera Wireless	BODY-WORN MONITOR FOR MEASURING RESPIRATORY RATE
Sotera Wireless	BODY-WORN VITAL SIGN MONITOR
Sotera Wireless	BODY-WORN VITAL SIGN MONITOR
Textronics	TEXTILE-BASED ELECTRODE
Zoll Medical Corp	WEARABLE AMBULATORY MEDICAL DEVICE WITH MULTIPLE SENSING ELECTRODES
Zoll Medical Corp	ELECTROCARDIOGRAM IDENTIFICATION
Zoll Medical Corp	RESCUE PERFORMANCE METRIC
Zoll Medical Corp	VCG VECTOR LOOP BIFURCATION
Zoll Medical Corp	RESUSCITATION ENHANCEMENTS
Zoll Medical Corp	TRANSMITTING TREATMENT INFORMATION
Zoll Medical Corp	SELECTION OF OPTIMAL CHANNEL FOR RATE DETERMINATION
Zoll Medical Corp	INTEGRATED RESUSCITATION APPARATUS AND METHOD INCLUDING PERFUSION MONITOR
Zoll Medical Corp	METHOD OF MEASURING ABDOMINAL THRUSTS FOR CLINICAL USE AND TRAINING
Zoll Medical Corp	RESCUE PERFORMANCE METRICS FOR CPR AND TRAUMATIC BRAIN INJURY
Zoll Medical Corp	Real-Time Evaluation of CPR Performance
Zoll Medical Corp	WEARABLE MEDICAL TREATMENT DEVICE WITH MOTION/POSITION DETECTION

Zoll Medical Corp	RESCUE SCENE VIDEO TRANSMISSION
Salutron	INTEGRATED SENSOR MODULES
Salutron	CLIP ADAPTOR FOR AN ACTIVITY MONITOR DEVICE AND OTHER DEVICES
Salutron	Energy Expenditure Computation Based On Accelerometer And Heart Rate Monitor
Salutron	PULSE WIDTH CODING WITH ADJUSTABLE NUMBER OF IDENTIFIER PULSES BASED ON CHANGE IN HEART RATE
Salutron	PULSE WIDTH CODING FOR INTERFERENCE-TOLERANT TELEMETRIC SIGNAL DETECTION
Salutron	HEART RATE MONITOR WITH CROSS TALK REDUCTION
Salutron	Electrostatic Discharge Protection For Wrist-Worn Device
Salutron	Electrostatic discharge protection for analog component of wrist-worn device
Salutron	EKG based heart rate monitor with digital filter and enhancement signal processor
Samsung Electronics	Electrocardiogram Watch Clasp
Samsung Electronics	METHOD AND APPARATUS FOR MEASURING THE DIFFERENCE OF PULSE WAVE VELOCITY IN MOBILE DEVICE
Samsung Electronics	ELECTROCARDIOGRAM SENSOR AND SIGNAL PROCESSING METHOD THEREOF
Samsung Electronics	FUNCTION OPERATING METHOD BASED ON BIOLOGICAL SIGNALS AND ELECTRONIC DEVICE SUPPORTING THE SAME
Samsung Electronics	WEARABLE BODY SENSOR AND SYSTEM INCLUDING THE SAME
Samsung Electronics	METHOD FOR PROCESSING DATA, SENSOR DEVICE AND USER TERMINAL
Samsung Electronics	WEARABLE DEVICE AND MANAGING DEVICE FOR MANAGING A STATUS OF USER AND METHODS THEREOF
Samsung Electronics	METHOD AND APPARATUS FOR RECOGNIZING IDENTIFICATION IN PORTABLE TERMINAL USING TOUCHSCREEN
Samsung Electronics	APPARATUS AND SENSOR OF MEASURING BIO SIGNAL, APPARATUS AND(...)
Samsung Electronics	CARD TYPE HANDHELD TERMINAL FOR MEASURING PHYSIOLOGICAL SIGNAL
Samsung Electronics	Apparatus and method for attaching biosignal measurement sensor to subject
Samsung Electronics	Portable device having biosignal-measuring instrument
Samsung Electronics	Method, medium, and apparatus measuring biological signals using (...)
Zephyr Technology	SYSTEM METHOD AND DEVICE FOR MONITORING A PERSON'S VITAL SIGNS
Scanadu Inc	PORTABLE DEVICE WITH MULTIPLE INTEGRATED SENSORS FOR VITAL SIGNS SCANNING
Scanadu Inc	PORTABLE DEVICE WITH MULTIPLE INTEGRATED SENSORS FOR VITAL SIGNS SCANNING
Infobionic Inc	SYSTEMS AND METHODS FOR DISPLAYING PHYSIOLOGIC DATA
Infobionic Inc	REMOTE HEALTH MONITORING SYSTEM
Mc10	CONFORMAL SENSOR SYSTEMS FOR SENSING AND ANALYSIS OF CARDIAC ACTIVITY
Mc10	ELECTRONICS FOR DETECTION OF A CONDITION OF TISSUE

8.3 Products List

Empresa	Produtos
AliveCor	AliveCor Mobile ECG
bOMDIC	GoMore

Casio	Phys
Medtronic	Seeq MCT
Textronics (Adidas)	Numetrex
OMSignal	OM Bra
	OM Smart Shirt
Zephyr	Bioharness 3
	HxM Smart
Polar	H7 HR Sensor
	For Manufacturers
Sotera Wireless	Visi Mobile
Zoll Medical Coportation	LifeVest
Salutron	lifetrak
	S Pulse
Samsung Electronics	Bio Processor
Scanadu Incorporated	Scanadu Scout
Infobionic	MoMe
MC10	biostamp