FONDAZIONE ISTITUTO ITALIANO DI TECNOLOGIA

A TECHNOLOGY TEASER

FORCE/TORQUE SENSORS

Released on April 2015

ROBOTICS

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- develops innovative methods and know-how, in order to facilitate new high-level practices and positive competitive mechanisms in the field of national research;
- promotes and develops scientific and technological excellence, both directly, through its multi-disciplinary research laboratories, and indirectly, through a wide collaboration with national and international laboratories and research teams;
- carries out advanced training programs as a part of wider multi-disciplinary projects and programs;
- fosters a culture based on sharing and valuing results, to be used in order to improve production and for welfare-related purposes, both internally and in relation to the entire national research system;
- creates technological understanding about components, methods, processes and techniques to be used for the implementation and interconnection of innovative products and services, in strategic areas for the competitiveness of the national production system;
- pools research scientists operating in various research institutes and establishes cooperation agreements with high-level, specialized centers;
- promotes interactions between basic research and applied research facilities, encouraging experimental development;
- spreads transparent, merit-based selection mechanisms for research scientists and projects, in compliance with globally approved and established criteria.

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EXECUTIVE SUMMARY

Force/Torque measurement and control are critical parameters in most rotating parts, machines and devices to ensure high quality and performance optimization of a process or a system. With increased awareness regarding the importance of torque measurement, torque sensors have paved their path in several fields such as medical prosthetics, electric & hybrid automobiles' engines and so on.

For example, force and torque sensors enable the possibility for machines to grasp and manipulate different items: this ability can be appealing in various circumstances. These sensors increase the versatility of machines and their potential applications. Their demand is rising in almost all industries where the need for automation is increasing. IIT solution has to be inserted in this framework.

This technology represents a unique chance for companies active in the markets of force/torque sensors and haptic devices. IIT assets appear well positioned for an out-licensing strategy, providing the licensee partner with the ability to take care of the late stage development, CE certification, scale-up and production process. The licensee should guarantee a high probability of market success based on consolidated marketing & distribution organization. A typical licensing strategy based on entry fee and subsequent royalties on net sales can be envisaged.

In the following paragraphs an IP outlook and a description of the IIT technology are available. Furthermore, the IIT Business and Financial Analysis Office (BFAO) implemented a market analysis and a competitive analysis highlighting the profiles of the most active industrial players in the sector.

INTELLECTUAL PROPERTY

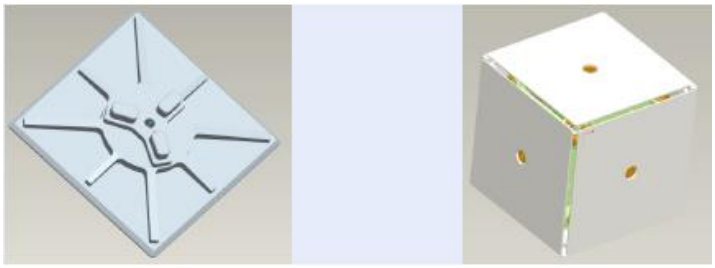
PCT International Application #	PCT/IB2013/059323- 11 October 2013
Priority Application #	IT 102012902091620 (TO2012A000890) - 11 October 2012
Regional Patent Applications filed	**US** 14/435154, **EP** 13812116.5**, CN** 201380053477.X
Applicant	Fondazione Istituto Italiano di Tecnologia
Inventors	SARAKOGLOU Ioannis, TSAGARAKIS Nikolaos, CALDWELL Darwin.
Title	Electronic Measurement Unit For A Polymorphous Device For Force Measurement And Polymorphous Device Including The Same

Short Description

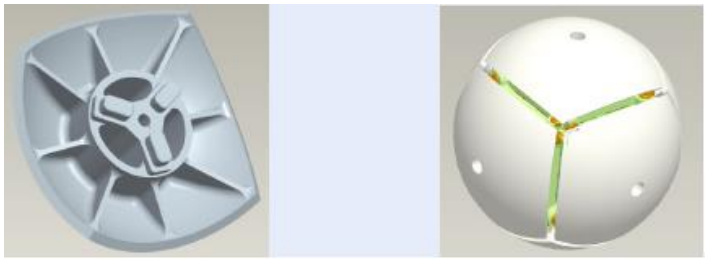
An electronic measurement unit for a polymorphous device, comprising a number of lateral structures, each lateral structure including: a support structure; at least one sensor constrained to the support structure and generating an electrical signal indicative of a deformation of the support structure; and a coupling structure that constrains a corresponding external covering element to the support structure in a releasable manner, so that when the external covering element is constrained to the support structure and an external force acts on the external covering element, the electrical signal is indicative of the external force.

IIT TECHNOLOGY

The invention consists in a polymorphic instrumented object which can measure multiple finger contacts on its surface (positions, forces and torque) when grasped and manipulated. The device can be used by humans or by robots to measure grasp forces. It is described as polymorphic because with the attachment of different faces on a single instrumented core it can take various different shapes, such as a sphere, a cube, a cylinder, etc and other arbitrary shapes. The instrumented core is a cube made from an assembly of six force/torque sensors. On each sensor is attached one external face. The objects' instrumented core contains all instrumentation and interface electronics for the measurement and for the connection to a computer.



An instrumented Cube. Attaching the Flat faces an instrumented cube can be created.



An Instrumented sphere. Attaching the spherical faces an instrumented sphere is created.

An Instrumented cylinder. Attaching the spherical faces and an instrumented cylinder is created.

In various scientific, medical and computer interfacing tasks it is desirable to measure the interaction forces of the hand with different objects. It is therefore necessary to have a proper measuring instrumentation which can resolve these interactions. There is also the need to perform grasp measurement with objects of different shapes. Actually one of the main drawback in this type of sensors is that the grasped object must have an ordinary geometrical shape (e.g. sphere, cube, and cylinder) or, at least, an arbitrary shape may be desirable. The IIT technology overcome this drawback with an apparatus that provides various object

shapes. When performing a grasp, the hand can employ two or more fingers placed around the object. Therefore, the instrumentation must provide the ability to measure multiple contacts which can have arbitrary locations on the surface of the grasped object. It is also desirable that the object can be approached, grasped and manipulated intuitively and naturally. Therefore, the instrumentation components should not pose mechanical or other obstructions which may interfere with the natural human behavior and grasp. Current instrumentation systems do not offer all of the above functionalities in a single portable and ergonomic device of an ordinary geometrical shape (e.g. sphere, cylinder, cube, etc). There exist technological challenges in resolving arbitrary contacts which include information about both contact forces and the position of contact in a portable instrumented object. Current instrumented objects are experimental or application specific designs which measure the forces at the specified finger contact locations or the grasp forces irrespective to finger position on the object.

Technical solutions provided by the invention

- This is a polymorphic instrument. It can take different shapes by means of mounting different contact faces on a single instrumented core. The shapes that the device may take can be simple geometrical primitives such as a cube, a sphere and a cylinder, or more complex shapes with arbitrary surfaces. The instrumented core consists of 6 force/torque sensors assembled to form a cube. On every one of the 6 sides of this instrumented core is mounted an interaction face. By mounting the interaction faces on the instrumented core the desirable shape for the object is created. This method solves the problem of needing a dedicated instrument for each object geometry. The instrumented core contains all the sensors, instrumentation, conditioning electronics and communication interfaces for connection to a computer.
- Each of the 6 faces of the instrument core can resolve one resultant force vector applied anywhere on its surface. Therefore 6 contact force vectors can be measured with the device. Each contact force vector can be arbitrarily located on one face. This method is able to measure many different grips due to the fact that each contacting finger's force vector is individually placed on an interaction face. When more than one point of force application exists on a face then the resultant force vector is measured.
- Each of the 6 sensors of the instrumented core provides 6DoF measurement, which is the forces and torques at the coordinate frame of the sensor. Using methods similar to those described in (Bicchi, Salisbury et al.), the force and torque measurements at the sensor's coordinate frame can be used to resolve both the force and the position of the contact of a finger on an external face with respect to the sensor's frame. Therefore, in situations where any face of the device is contacted in a single arbitrary location it's possible to resolve both the contact force vector and the locations of the contact on the apparatus' surface. This allows the user to interact with the object intuitively without the need to apply the grip forces on predetermined locations.
- The instrumented object is user friendly, portable and allows intuitive handling by the user. The described instrumentation is composed of a core containing all the measuring elements and enclosing non obstructive electronics.

MARKET ANALYSIS

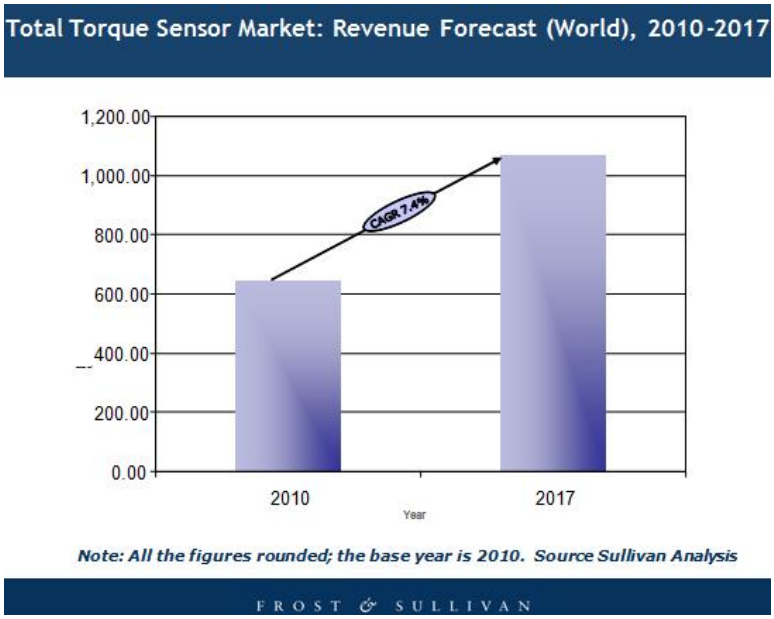
Based on the technology described in WO 2014/057479, IIT internal documentation on the technology and related literature publications by the inventors and competitors, three major markets have been identified, namely the **Force/Torque Sensors Market,** the **Hand Physiotherapy** market and the **Haptic Devices** market. These markets have been analyzed for their current dimension and future trends through a web search-based retrieval of free-of-charge specific information. The first market described represents the macro category within which IIT technology can be placed. Nonetheless, the object of the patent considered seems to depart from it and to better fit the physiotherapy and haptic device markets.

Force/Torque Sensors Market Overview

Torque measurement and control is a critical parameter in most rotating parts, machines and devices to ensure high quality and performance optimization of the process or the whole system.

All reports taken in consideration assume an increase in the value of the market for Torque sensors, with small variations in terms of CAGR (Compound Annual Growth Rate). The "*Torque Sensor Market - By Technology (Rotary, Static/Reaction, Magneto Elastic, IR, SAW, Optical), Application (Automotive, Industrial, Test & Measurement, Aerospace & Defense, Medical) and Geography, Global Forecast & Analysis (2013-2018)*", published by **MarketsandMarkets**, identifies the value of torque sensor market at around $869.73 million in 2012 and is expected to reach $1427.78 million in 2018, at an estimated CAGR of 8.5% from 2013 to 2018. In terms of volume, the total number of torque sensors shipped in 2012 was 525.78 thousand and the number is expected to reach 969.84 thousand by 2018.

Frost & Sullivan, on the other hand, projects an estimate CAGR of 7.4% from 2010 to 2017, in their report "World Torque Sensors Market" published in 2011, going from a $647.1 million to $1.06 billion in the considered period, as it can be appreciated from the graph below.



Geographical Focus: USA and Europe

The torque sensor market in **North America** is segmented on the basis of different types of sensors used, such as rotary, static/reaction, magneto elastic, surface acoustic wave (SAW), and optical. Rotary and reaction torque sensors together accounted for approximately 86% of the total market in this region. North America is one of the most technically advanced application markets for torque sensors due to the presence of prominent system suppliers, large semiconductor companies, competitive aerospace & defense, and medical OEMs in this region. Medical applications, which is currently a niche market for torque sensors, is expected to witness considerable growth with the emergence of medical robotics and the increasing demand for better healthcare services among consumers.

The North American torque sensor market is expected to grow from $295.8 million in 2013 to $422.4 million by 2018, at a CAGR of 7.4% from 2013 to 2018. In North America, the United States is the largest market mainly connected to automobiles sales, which pushes forward the demand for torque sensors.

The torque sensor market in **Europe** is also segmented on the basis of different types of sensors, but in this region rotary and reaction torque sensors together accounted for around 87% of the total market share. Europe ranks second in the production of light vehicles after Asia-Pacific. The region produced approximately 18 million light vehicles in 2012 which is a major market for torque sensors. This region is gradually recovering from the global recession and is expected to exhibit greater demand for torque sensors. Europe is a major center for Formula 1 racing, which is currently one of the largest application markets for magneto elastic torque sensors.

The European torque sensor market is expected to grow from $257.2 million in 2013 to $381.1 million by 2018, at a CAGR of 8.2% from 2013 to 2018. In Europe, the U.K. is the major market for torque sensors, followed by Germany. The latest development in wireless and non-contact torque sensors such as optical torque, magneto elastic, and acoustic wave (SAW) will increase the use of torque sensors in various verticals.

Applications

Torque sensors have been mainly used for engine and transmission testing, turbine testing, pump testing, and measurement of power within propulsion systems. In order to distinguish specific applications in terms of end users, the following emerge:

Automotive: Automotive is currently the largest application segment of torque sensors with wide range of applications such as dynamometers, steering systems, transmission, chassis performance and driveline. Recently, magneto elastic torque sensors have made their way into automotive applications and are being used in racing applications by a number of Formula 1 teams. Many more automotive applications have emerged during the last few years with numerous technological advancements and continuous demand in the market for precise and accurate torque measurement. In 2010, revenues from this particular market segment contributed 55.8% to the total.

Industrial: Torque has become an essential indicator in stating the health of a machine on the industrial floor as they measure torque and facilitate rotational movements that need continuous monitoring. Revenues from industrial end users in 2010 contributed 23.3% of the total torque sensor revenues and this is estimated to increase to 24.1% in 2017.

Aerospace & Defense: Revenues from torque sensors in the aerospace industry contributed 1.1%. There are two reasons for it: the prime being that production of non-Robinson helicopters is estimated to be lower than Robinson helicopters, which do not use torque sensors. The other is the higher adoption of torque sensors by the other end-user segments.

Medical: Revenue from medical end users is estimated to increase in 2017 with an annual rate of 4.5% in 2010. The report does not specify the amount but the general trend is towards a massive increase both in the rehabilitation and surgical robotic markets due to increase in population age within advanced countries.

Others: Other end-user segments include revenues from both custom end users and a large number of diverse end users. As more end users recognize the benefits of using torque sensors and increasingly adopt their use, revenues are likely to increase by 2017.

Torque measurements have been performed across a wide range of industry verticals since the onset of the 20th century driven by a number of factors further described in the following paragraphs. This in turn lead to a proliferation of new technologies. While earlier techniques of torque measurement involved resistive and piezo-resistive strain gauge methods, some of the recent techniques involve technologies such as infrared (IR), magneto elastic, optical and surface acoustic wave (SAW). The last three are categorized within the non-contact and wireless group and have opened doors for numerous potential applications of these sensors such as in medical robotics, diagnostic equipment, and racing applications.

Other applications for torque sensors that are gaining traction in the market are telemetry, prosthetics in medical applications, turbo-engine applications in aerospace, and engines in electric and hybrid vehicles. Their superior response times also make them ideal for many electronic applications.

Growth Drivers

There are several factors that are going to increase adoption of torque sensors in the future:

1. Quality control specifications like ISO 9000 have played a vital role in the growth of torque sensor market especially in the United States, Canada, Germany, the United Kingdom, and France. The demand for accurate torque measurement solutions is increasing in a phenomenal manner, supporting the huge growth potential for torque sensors.
2. The rising importance of torque testing in the assembly of safety-related components and equipment will give a huge boost to the demand for torque sensors.
3. The market will also get a shot in the arm with the rapid expansion of aircraft fleet in the Asia Pacific. With larger numbers of aircraft being manufactured, there will be a corresponding rise in the sales of torque sensors.
4. The sensors' role in continuously monitoring and measuring helicopters' operations will also stand in good stead, as these machines are the primary modes of transport to and from offshore oil rigs and other remote oil fields. With diminishing supplies of fuel driving fuel companies to drill in more distant areas, torque sensor companies will find a vast market in the aerospace end-user sector.
5. Development of wireless torque sensors as well as the industrial, medical and test and measurement segments are expected to promote growth and expand the torque sensor industry in the future.

Challenges

This diversity of applications is both an opportunity and a serious challenge for manufacturers, as they need to orient torque sensors to the designs of the equipment, device, machinery, or instrument where the torque is to be used. In the aerospace industry, torque sensors have very critical applications as tremendous torque is generated while helicopters or aircraft are flying. Likewise, in prosthetics or robotic surgery, torque design and precise measurements of torque attain great importance to ensure precision. Within industrial applications, reaction and rotary torque types are offered to satisfy many applications, including electric motor testing, dynamometers, hydraulic pump testing, fan testing, and torsion test machines. Load ranges and measurements of torque range from 50 in-oz or grams to 2 million lbf.

Knowing the options available to make the connection with the rotating parts, torque sensor can greatly affect the price of the sensor package. An analyst noted for example that “while sliprings are an economical solution, but inadequate, the more technically advanced solutions are more expensive” and that “to assess the exact nature of the torque to be measured, as well the factors that can alter that torque in the effort to measure it, will have a profound impact on the reliability of the data collected.”

Haptic Devices Market

According to the market research report of *"Haptic Technology Market for Touchscreen (2013- 2018): By Components (Kinesthetic & Tactile Sensing, Actuators); Technology (Resistive, Capacitive); Devices (Touchscreens, Input Devices); Applications (Consumer Electronics, Automotive, Medical)",* published by MarketsandMarkets, is expected to grow at a CAGR of 41% from 2013 to 2018 and reach $51.77 billion in 2018.

The focus for the technology at hand is on Input Devices which represent the connection between human and machine as they allow movements and forces to be transmitted to and from the output device. The market taken into account is in particular the one of Virtual Reality (VR) which sees its major application in gaming. Input Devices can be used though in other markets such as the Teleoperation one, by allowing the surgeons to operate on patients far from their location.

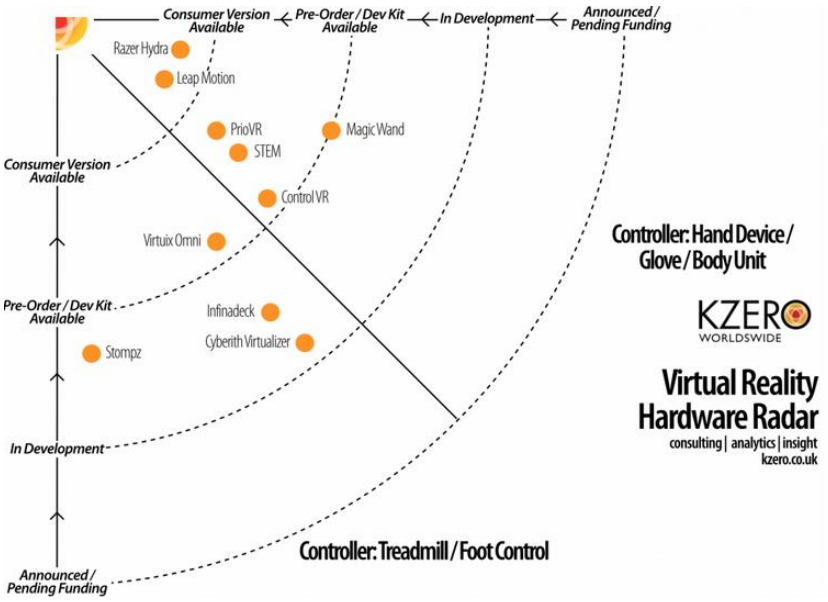
For what concerns VR Hardware we can further distinguish between head mounted displays (HMDs) and input system devices such as gloves, treadmills and bodysuits as well as haptic feedback outputs. The consulting company KZero suggests that the addressable markets in the VR hardware market along with penetration assumptions and unit sales forecasts are the following:

- Forecasted penetration for consumer VR headsets reached 8.8% in 2015.
- Forecasted penetration for consumer VR Input Systems reached 26.3% in 2015.
- By 2018 they estimate total HMD unit sales of almost 39m globally. This equates to a cumulative total of 83m HMD unit sales over the five-year period.
- By 2018 they estimate total VR Input System unit sales of almost 10m globally. This equates to a cumulative total of 18m unit sales over the five-year period.

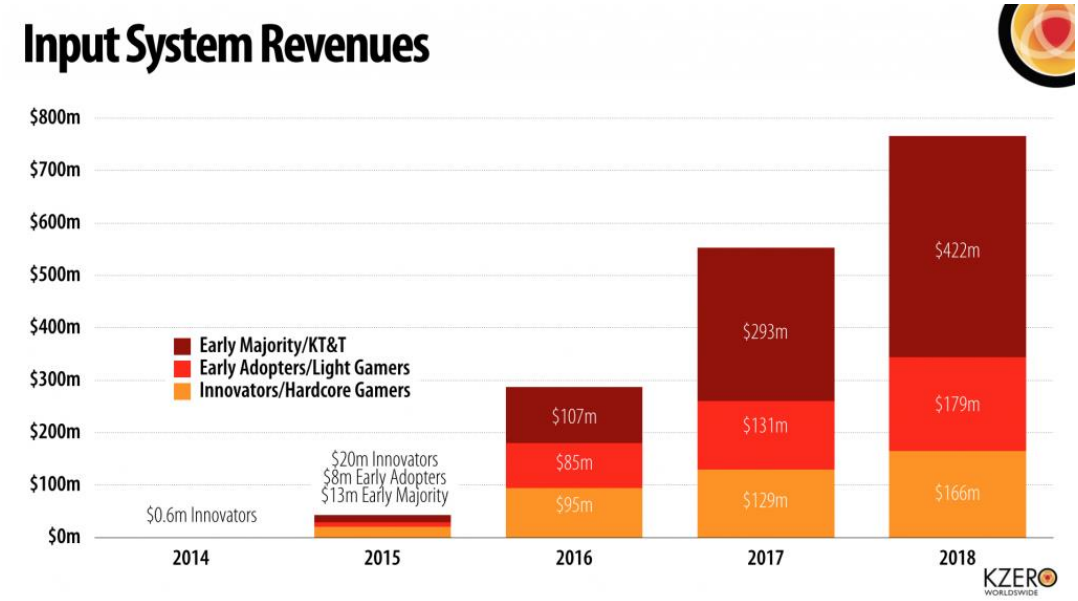
The VR hardware market can be segmented into eight different categories, as follows:

- HMD – Integrated: A virtual reality head-mounted display with the screen integrated into the unit. This segment includes Oculus VR, as well as companies such as VRelia, Gameface Labs, Avegant, Sony and ANTVR.
- HMD – With Mobile Device: A virtual reality head-mounted display using a third-party mobile device as the screen. Companies in this segment include Durovis, Seebright, Altergaze, Vrizzmo and Samsung.
- Controller – Hand Device / Glove / Body Unit: An input device using hands and/or body movement for tracking via sensors. PrioVR, STEM, Control VR and Leap Motion are all included in this element of the market.
- Controller – Treadmill / Foot Control: An input device that tracks leg/foot movements. In this category we include Virtuix Omni, InfinAdeck, the Cyberith Virtualizer and Stompz.
- Controller – Haptics: An input device for hands and body that also provides tactile feedback by force or vibration. The KOR-FX Gaming Vest, iMotion and the Reactive Grip are three of the products included here.
- 3D Camera: A video or image recording device that captures 3D stereoscopic views. Jaunt, Giroptic and Matterport are within this grouping.
- End-to-End Platform: A company that provides HMD systems coupled with input devices and motion capture. This category brings together companies that are creating VR experiences encompassing HMDs, input devices, games and other elements. Survios and VRCade are two examples.
- Misc: Products not fitting into other categories.

Based on the stage of development in which the aforementioned players find themselves, the following map portrays visually the competitive space of the VR Hardware market.



KZero's 2014 – 2018 forecast for revenues (http://www.kzero.co.uk/blog/vr-hmd-and-input-system-device-revenue-forecasts-2014-2018/) from the VR Input Device market segment is shown below. 2014 market activity is low and primarily from Kickstarter-funded companies. In 2015 they envisage a growth in supply of Input Devices from HMD manufacturers (Oculus, Sony, Samsung) along with standalone companies basing their business models solely around these devices.



Hand Physiotherapy Market

The technology developed by IIT researchers can be used in the rehabilitation field, with focus on hand and wrist as it can measure force expressed through gripping (instrumented object) thus providing an objective feedback concerning the effects of the rehabilitation exercises. Moreover, it can be used as a component of hand exoskeletons able to help patients regain mobility of their hand after a stroke or other trauma.
Therefore, we look at the dimension of this market from two points of view: the first concerns the number of rehabilitation centers that might be interested in acquiring these products, and second the number of patients that might want to practice and exercise in the comfort of their homes, through so-called tele-rehabilitation (which is the delivery of rehabilitation services over telecommunication networks and the internet).

According to Nature[1] rehab devices are in huge demand. Stroke is the world's leading cause of severe disability. In the United Kingdom alone, more than 150,000 people have a stroke in any one year, and about 1.1 million people are living with the consequences, more than half of whom need help to carry out their everyday activities. And because the world's population is ageing, the number of people who have strokes will only increase. Stroke usually causes paralysis or weakness on one side of the body, but the injuries can

[1] http://www.nature.com/nature/journal/v510/n7506_supp/full/510S8a.html

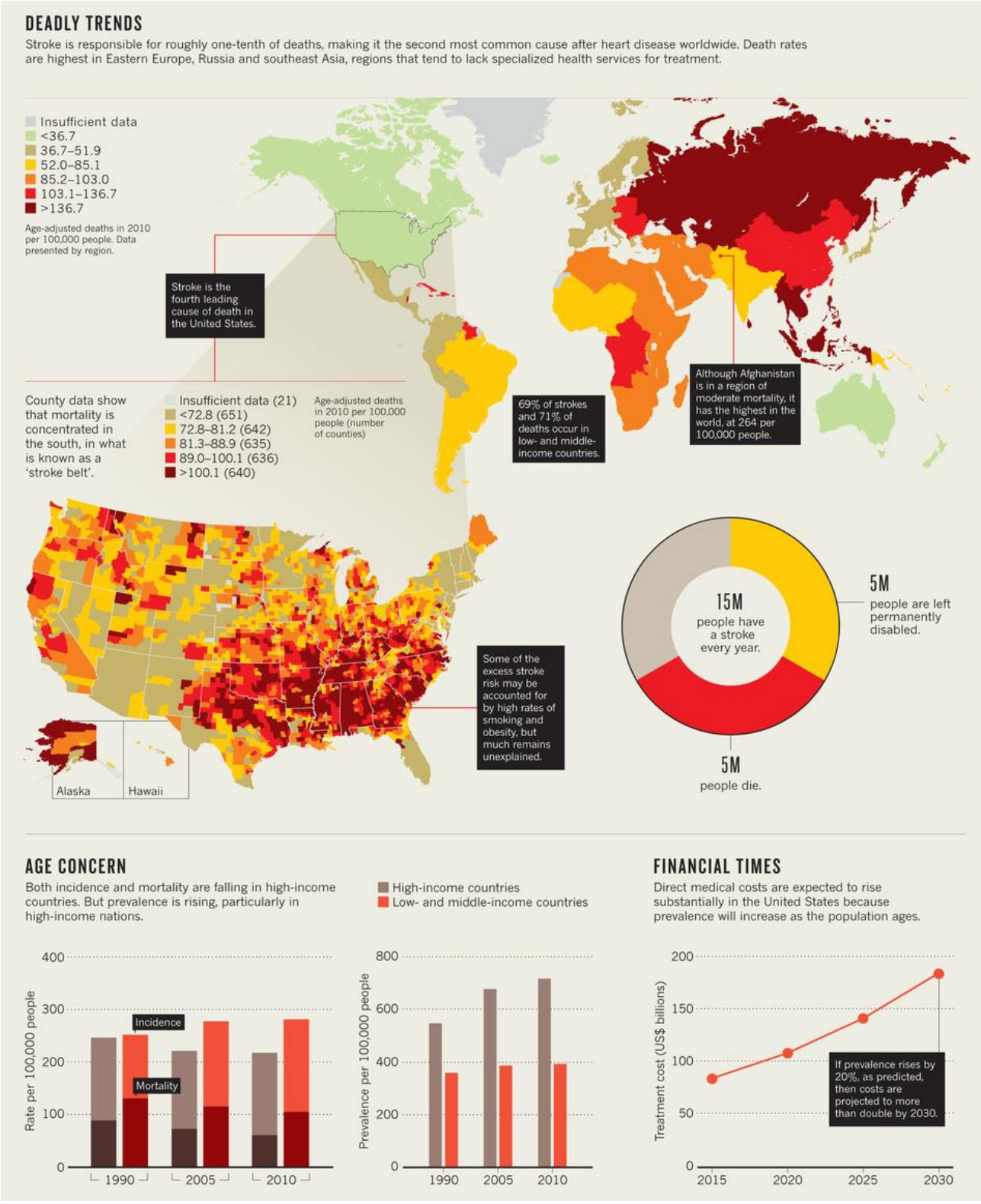
often be treated through intensive training that involves repetitive movements of the affected limbs. The process is time consuming and laborious for both patient and therapist.

Machines are already invaluable in rehabilitation — they measure patients' progress with great accuracy and are widely used to compare the outcomes and identify the people most likely to benefit from therapies. Some researchers think that machines will transform the way in which treatment is delivered. As the cost of technology drops, that of manual labor rises; researchers hope that robots will not only lend help to deliver the intensive therapy needed for stroke recovery, but also do it more cost-effectively.
Research interest in rehabilitation devices has grown over the past 20 years. A survey published in January 2014[2] by Paweł Maciejasz, Jörg Eschweiler, Kurt Gerlach-Hahn, Arne Jansen-Troy and Steffen Leonhardt lists more than 120 devices for arm rehabilitation alone, ranging from passive braces for the shoulder to complex exoskeletons that actively assist users in performing certain movements[3].

Market Size

The size of the market can be gauged by looking at the number of *stroke patients* that survive but are afflicted by mobility limitations as a direct result and at the number of *Rehabilitation Centers* where the product might be adopted. The following infographic depicts the first group.

[2] http://www.jneuroengrehab.com/content/11/1/3
[3] http://www.jneuroengrehab.com/content/11/1/3/table/T1



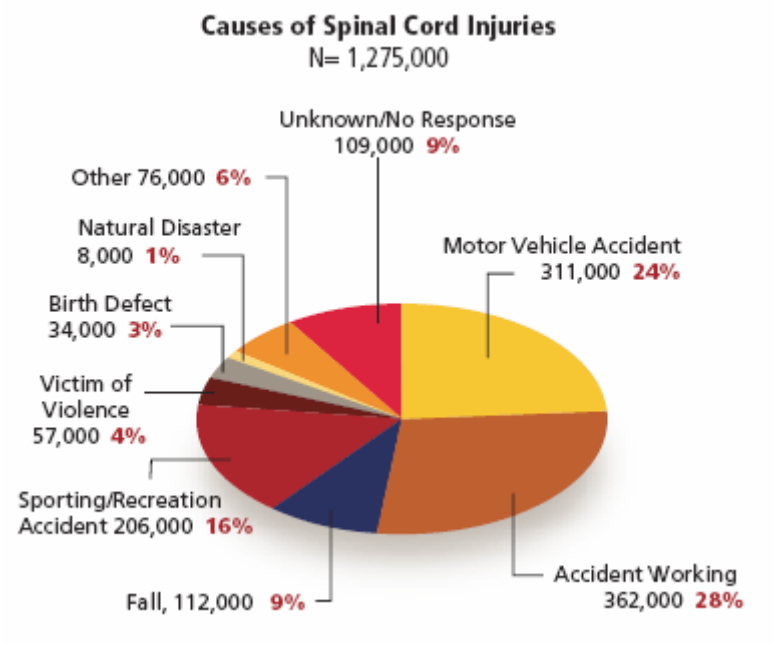
Another important proxy can be seen in the number of patients who suffer from *spinal cord injuries*. According to a study initiated by the Christopher & Dana Reeve Foundation, in the United States, there are nearly 1 in 50 people living with paralysis -- approximately 6 million people. That's the same number of

people as the combined populations of Los Angeles, Philadelphia, and Washington, D.C. And that number is nearly 40% higher than previous estimates showed.

The costs of living with SCI can be considerable, and vary greatly due to the severity of injury. The following facts are according to The University of Alabama National Spinal Cord Injury Statistical Center and the Centers for Disease Control and Prevention.

- Average yearly expenses can range from $228,566 to $775,567 in the first year.
- Estimated lifetime costs due to spinal cord injury can range from $681,843 to over $3 million for a 25-year-old person.
- 87.9% of all spinal cord injured individuals are discharged from hospitals to private homes.

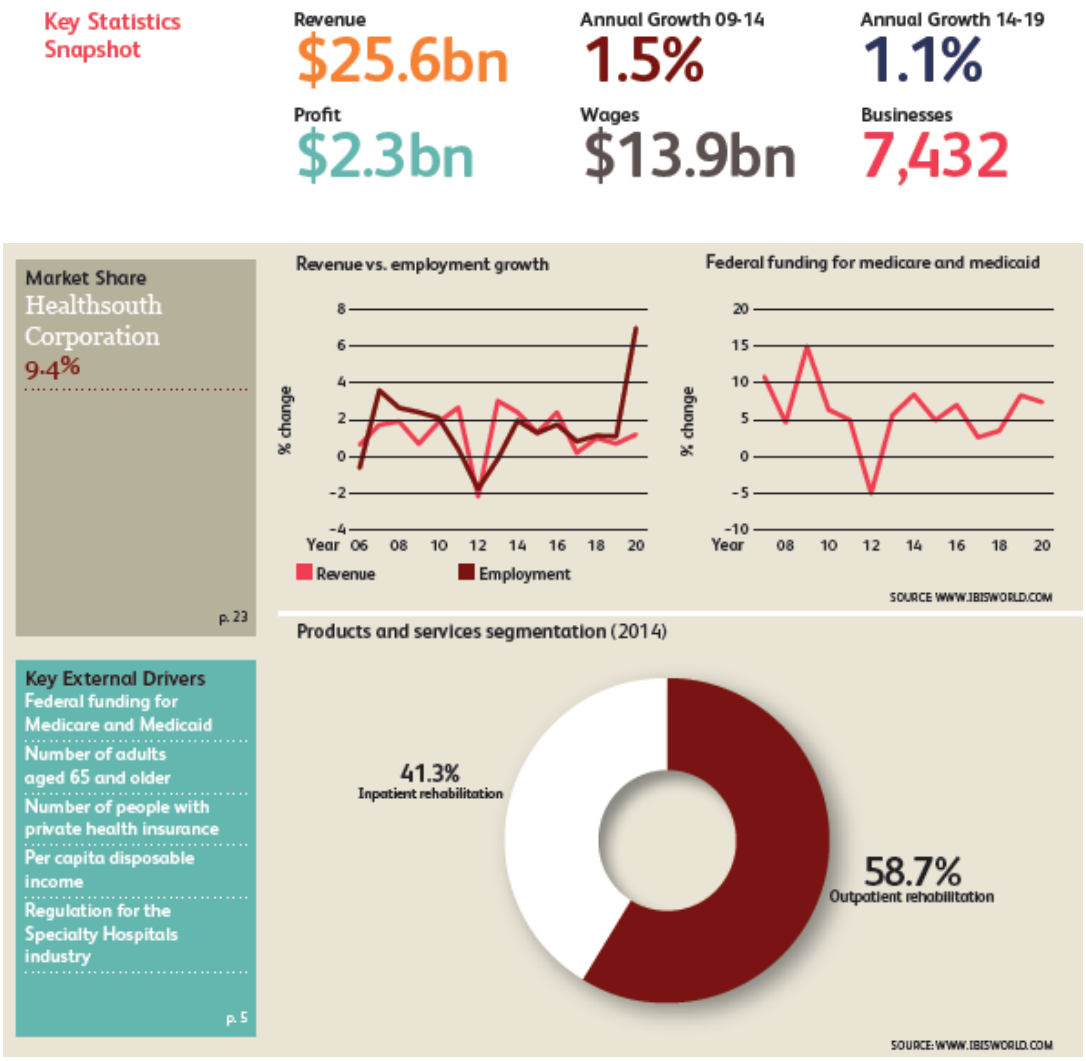
The causes of Spinal Cord Injuries are depicted as follows:



According to the report "Physical Therapy Rehabilitation Centers in the US Industry Market Research Report from IBISWorld", the **Physical Therapy Rehabilitation Centers industry** is comprised of both inpatient and outpatient therapy facilities that provide physical, speech pathology and occupational therapy services. In the five years to 2014, the industry experienced revenue growth as a result of the aging population and increasing acceptance of the benefits of physical therapy services. Seniors are more likely to require physical therapy services because of injuries, illnesses and a range of other chronic conditions. Over the past five years, industry revenue increased at an annualized rate of 1.5% to $25.6 billion.
Instead of a global overall decline in revenue, this industry experienced a rapid rate of consolidation. The number of industry establishments fell at an average annual rate of 2.1% to 24,907. The trend of consolidation was likely triggered by the 6.0% decline in Medicare reimbursements in 2011, which was followed by further reduction in 2012. The decline in reimbursements prompted industry revenue to

contract in 2012, but revenue rebounded with 3.0% growth in 2013 and is expected to grow by as much as 2.4% in 2014.

Continued expansion of the aging population, healthcare reform and economic recovery are expected to support industry revenue growth in the five years to 2019. To this end, IBISWorld forecasts industry revenue will increase at an average annual rate of 1.1% to $27.1 billion in the five years to 2019, slightly slower than during previous five-year period.



Industry Structure

Life Cycle Stage	Mature	Regulation Level	Heavy
Revenue Volatility	Low	Technology Change	Medium
Capital Intensity	Low	Barriers to Entry	Medium
Industry Assistance	High	Industry Globalization	Low
Concentration Level	Low	Competition Level	High

One of the reasons why this market represents an interesting opportunity for the technologies developed within IIT is that physical therapists are decreasing in number while their wages increase. The cost of labor and an aging population are two key drivers for adoption of robotic applications which ease and standardize therapists' job. By employing such technologies, it is possible to treat more patients at the same time thus increasing productivity. This aspect is further demonstrated by the data provided by the

IBIS World Report: “The industry is also contending with a shortage of necessary professionals: therapists. In the five years to 2014, industry employment grew marginally at an annualized 0.5% to 287,609 people. Alternatively, industry wages rose by an average 1.7% annually during the same period to $13.9 billion. Industry operators can afford to maintain employment numbers during an economic downturn because demand for physical therapy services, especially from the growing population of older patients, does not substantially change. However, a shortage of therapists today has led to a rise in the average industry wage. Industry operators are forced to offer employees better pay packages in order to attract and retain employees”.

COMPETITIVE SCENARIO

Key companies in Force/Torque Sensors Market

The torque sensors market is extremely competitive. Most of the companies concentrate their efforts on the development of torque sensors for multiple applications**.** Measurement Specialties, Teledyne Instruments, FUTEK Advanced Sensor Technology, Honeywell Sensing and Control and ATI Industrial Automation are the key tier-one torque sensors market players.

- AIMCO Corporation (USA, http://www.aimco-global.com)
- AMTI (USA, http://www.amti.biz/)
- ABB Ltd. (Switzerland, http://www.abb.com/)
- Applied Measurements Ltd. (UK, http://www.appmeas.co.uk/)
- ATI Industrial Automation (USA, http://www.ati-ia.com/)
- Burster GmbH & Co. KG (Germany, http://www.burster.com/en/home/home.html)
- Crane Electronics Ltd (UK, http://www.crane-electronics.com/)
- Datum Electronics Limited (UK, http://www.datum-electronics.co.uk/)
- Esterline Technologies Corporation (USA, http://www.esterline.com/)
- FUTEK Advanced Sensor Technology (USA, http://www.futek.com/)
- Honeywell Sensing and Control (USA, https://sensing.honeywell.com/)
- Hottinger Baldwin Messtechnik GmbH (Germany, http://www.hbm.com/)
- Interface, Inc. (USA, http://www.interfaceforce.com/)
- JR3, Inc. (USA, http://jr3.com/products/products.html)
- Kistler Instrumente Ag (Switzerland, http://www.kistler.com/it/en/)
- Lorenz Messtechnik GmbH (Germany, http://www.lorenz-messtechnik.de/english/)
- MagCanica, Inc. (USA, http://www.magcanica.com/)
- Measurement Specialties (USA, http://www.meas-spec.com/)
- Mountz, Inc. (USA, http://www.mountztorque.com/)
- Norbar Torque Tools Limited (UK, http://www.norbar.com/it-it/)
- PCB Load & Torque, Inc. (USA, http://www.pcb.com/LoadAndTorque.aspx)
- Robotiq (Canada, http://robotiq.com/)
- S. Himmelstein and Company (US, http://www.himmelstein.com/)
- SCAIME SAS (France, http://www.scaime.com/)
- Sensor Technology Limited (UK, http://www.sensortech.ca/site/index.cfm)
- SENSY S.A. (Belgium, http://www.sensy.com/)
- Teledyne Instruments (USA, http://www.teledyneinstruments.com/)

Key companies in Haptics Technology Market

The competitive landscape of the market presents a very interesting picture. The market is witnessing new product launches, large scale collaborations, and agreements and partnerships across the value chain, with a number of tier-one players around the globe.

- 3D systems Corp (USA, http://www.3dsystems.com/)
- AAC Technologies Holdings, Inc. (China, http://www.aactechnologies.com/)
- Analog Devices (USA, http://www.analog.com/en/index.html)

- Alps Electric (Germany, http://www.alps.com/gps_e/)
- Atmel (USA, http://www.atmel.com/)
- Bluecom (Sweden, http://www.bluecom.se/)
- Cypress Semiconductor (USA, http://www.cypress.com/)
- Densitron Technologies Plc (UK, http://www.densitron.com/)
- Fairchild Semiconductor (USA, https://www.fairchildsemi.com/)
- Haption SA (France, http://www.haption.com/site/index.php/fr/)
- Hysonic (South Korea, http://www.hysonic.com/eng/)
- Immersion Corp (USA, http://www.immersion.com/)
- Jahwa Electronics (South Korea, http://www.jahwa.co.kr/index_eng.php)
- Johnson Electric Group (Hong Kong, http://www.johnsonelectric.com/)
- Maxim Integrated Products Inc. (USA,)
- Methode Electronics (USA, https://www.maximintegrated.com/en.html)
- NEC Tokin (Japan, https://www.nec-tokin.com/english/)
- Nidec Copal Electronics (Singapore, http://www.nidec-copal-electronics.com/e/index.html)
- Precision Microdrives Ltd (UK, https://www.precisionmicrodrives.com/)
- RAONTECH (South Korea, http://www.raon-tech.com/)
- Tactus Technology Inc. (USA, http://tactustechnology.com/)
- Texas Instruments, Inc (USA, http://www.ti.com/)
- Visteon (USA, http://www.visteon.com/)

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