FONDAZIONE ISTITUTO ITALIANO DI TECNOLOGIA

A TECHNOLOGY TEASER

IIT BIO-INSPIRED ROBOTS

ISTITUTO ITALIANO DI TECNOLOGIA

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ROBOTICS

Istituto Italiano di Tecnologia – Mission and History

The Foundation is intended to promote Italy's technological development and advanced education, consistent with national policies for scientific and technological development, thus strengthening the national production system.
For this purpose, the Foundation:

- helps and accelerates the development, within the national research system, of scientific and technological skills able to facilitate state of the art technological advancements of the national production system;

- 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

Although in the current market there are several tools able to pierce or penetrate a substrate, whether continuous or fluid, all the known techniques have important drawbacks with regard to the destructive interaction that the device has with the substrate. The actual approach, therefore, strongly limits the use of these technologies in all of those fields where the destruction of the environment must be avoided like medical or non-destructive inspection purposes. Conventional techniques also require the use of very high axial forces resulting in a large waste of energy during the drilling process. Mimicking the nature it's possible to create systems capable to penetrate a substrate in a more efficient way.

Three different solutions have been developed at IIT for the non-destructive penetration of a substrate. Two of them represent artificial growing robots that take inspiration from some features of a plant root while the last one mimic a worm movement behavior. The first one, capable to perform an efficient penetration without frictional effects, it's a self-growing hollow structure that can elongate the tip by adding new raw material from a reservoir with a layering-based technique. The second one is based on a cylindrical shaft and on an engineered skin; the device can penetrate a substrate by slipping out from the tip a self-anchoring structure that interacts with the surrounding environment without destructing it. The third device is based on two interlaced robots that perform an active exploration of a structured environment with a follow-the-leader approach.

These technologies represent a unique chance for companies interested, or willing to branch out, in medical devices market as well as in environmental analysis and non-destructive inspection markets. 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.

INTELLECTUAL PROPERTY

PCT International Application #
PCT/IB2014/062758 – 1st July 2014
Priority Application #
IT 102013902174624 – 12th July 2013
Applicant
Fondazione Istituto Italiano di Tecnologia
Inventors
Ali Sadeghi, Barbara Mazzolai
Title
System For Non-Destructive Penetration Of A Substrate

The technology has been granted the Italian Patent IT 0001419560 on 2nd December 2015. European Patent application EP 14747720.2, US Patent application US 14/904229 and Chinese Patent application CN 201480050390.1 are still pending.

Short description
The invention relates to a new robotic device able to grow, crawl, and dig. The main inspiration of this robotic is the capability of plant roots to penetrate the soil while they grow by adding cells from the tip. This system, which has a cylindrical shape, can develop its own body by adding artificial material and, consequently, can elongate and mimic the root behavior in penetrating and exploring the surroundings in an efficient way. The concept of a mechanical system that can grow leads to a new generation of robots which can create some parts of their body and adapt more safely to surrounding environments.

Priority Application #
IT 102013902152478 – 3rd May 2013
Applicant
Fondazione Istituto Italiano di Tecnologia
Inventors
Ali Sadeghi, Liyana Popova, Alice Tonazzini, Barbara Mazzolai
Title
Dispositivo Per La Penetrazione Autonoma E Non Distruttiva Di Ambienti

The technology has been granted the Italian Patent IT 0001417176 on 31st July 2015. The priority application was not foreign filed

Short description
The invention relates to the sector of robotic devices for the autonomous movement with a non-disruptive penetration of structured and non-structured environments like soil, rubbles or organic tissues. More particularly the invention relates to a device with a continuous three-dimensional track suitable for exploration, monitoring or diagnostic objectives.

PCT International Application #
PCT/IB2016/052396– 27th April 2016
Priority Application #
IT 102015902349212 – 27th April 2015
Applicant
Fondazione Istituto Italiano di Tecnologia, Scuola Superiore Sant'Anna
Inventors
Edoardo Sinibaldi, Byungjeon Kang, Risto Kojcev
Title
A Shape-Keeping Deployable Structure Including A Pair Of Robotic Systems Of The Continuum Type

Short description

The invention relates to a continuously steerable robotic probe composed of two interlaced continuum robots that advance over a chosen smooth trajectory by a follow-the-leader strategy. Physical track-building is achieved by an alternating method: each continuum robot is alternatively actively stiffened to guide the other, and loosened to be guided.

IIT TECHNOLOGY

Penetration mechanisms are commonly used in order to access lower layers of various substrates in several different industrial fields like water, oil and gas search, geology, soil analysis/purification, medical and inspection purposes. Some particular applications, in the mentioned areas of interest, present unique requirements not achievable with current techniques. In order to meet these requirements, IIT researchers have developed new devices that, taking inspiration from nature, are able to perform a non-destructive penetration and/or exploration of structured and non-structured environments. Thanks to their specific technological features, IIT devices may have among the others several applications in the biomedical field, in environmental analyses and in non-destructive inspections.

Three bio-inspired devices developed at IIT are briefly described below. Two of them are plant root-inspired mechanisms and the third one is an interlaced robot inspired by worm movements.

Plantoid A

Figure 1. Prospective view of the device

The device is made up of a cylindrical shape and can develop its own body growing with a layering technique that mimics the plant root behavior. This particular expanding mechanism allows the robotic system to overcome the resistances of any granular, clay-like or fluid-like substrates by eliminating the frictional effects in the peripheral body of the structure during the penetration.

The device is divided in two main sub-mechanisms: a creation center and a reservoir system.

The creation center, positioned on the tip of the system, comprises a distribution apparatus movable in a guided manner and a motor arranged inside the hollow structure. The distribution apparatus provides a given quantity of hardenable or solidifiable raw material towards the outside of the perimetric edge defining a tubular structure around the excavation assembly. The reservoir system provides the storage of the raw material and its displacement to the creation center.

The hollow structure formed during the penetration process allows transferring easily new raw material and powering to the creation center. On one side the process of growth and elongation from the tip, and on the other side the stationary behavior of the mature skin in relation to the environment, help the system to easily penetrate the surroundings avoiding the drawbacks of the devices available on the market.

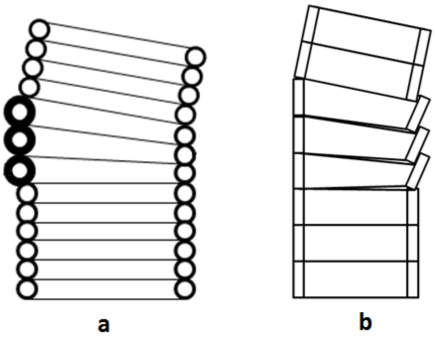

Figure 2. Twisted structure: a. different diameter of deposing filaments, b. twisted filaments during deposition

The device has the capability of steering and bending, by changing the diameter (Fig. 2a) or by controlling the torsional state (Fig. 2b) of the filament during the deposition process. These features allow the growing system to change its direction and/or to overcome obstacles.

A fully working prototype has been implemented (Fig. 3). The external diameter of the device is 50 mm with a 3.5mm diameter cotton filament as raw material.

Figure 3. Fully working prototype shown during the extension process

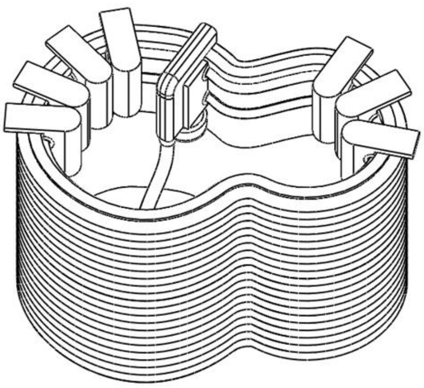

Figure 4. Extended device with a non-circular external shape

As shown in figure 4, the external shape of the device is not necessary circular. Other loop-like configurations might be used with minor changes in the disposition of the internal elements not altering the concept of the technology. In the displayed alternative layout, the body comprises at least one guide rail on which the motor and the distribution apparatus are slidably mounted.

The described device is able to perform a non-destructive penetration, reducing the peripheral friction between itself and the surrounding substrate while maintaining a hollow internal structure. These technical features could be useful for a wide range of industrial applications. The hollow structure and the passage that this system creates could be used for delivering several different materials, components, and tools, such as water, food, drugs, cameras, sensors, oxygen, power and surgery devices. Thus the system could be applied in different environments like agriculture, surgery, monitoring, rescue applications and maintenance tasks. More particularly it could be used for monitoring and maintenance of pipes (like oil, gas and water pipes) without blocking and interrupting the flow of the liquid. Moreover, its capability of working in slimy environments with a stationary interaction make it a suitable device for minimally invasive robotic flexible endoscopy.

Plantoid B

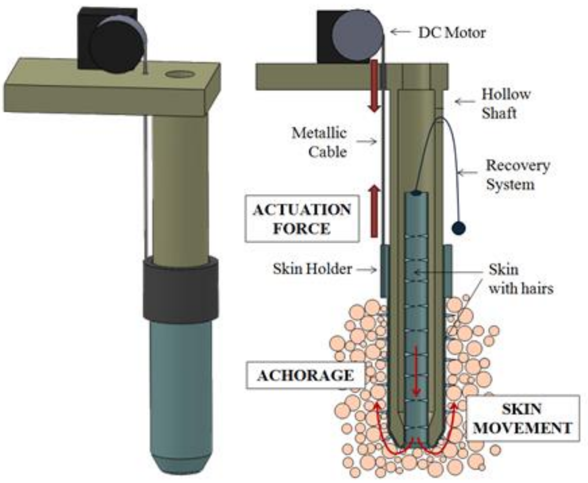

Figure 5. Schematic representation of the device and its interaction with the environment

The system is composed of three main components:

1) a hollow cylindrical shaft;
2) a soft and flexible cylindrical "skin";
3) a "skin" actuation system.

The "skin" is stored inside the shaft and can migrate from the hole, located on the tip of the device, to the external part of the shaft. The "skin" remains close to the external surface of the shaft but it's free to slide on it (Fig. 5). The movement of the "skin" imitates the sloughing behavior of root border cells, having an outward movement from the tip mimicking the generation of new cells in a plant root. This feature provides a low friction interface between the shaft and the substrate.

The part of the "skin" on the tip adheres to the external environment during its outward movement and pushes the surroundings particles aside. This displacement creates a gate in front of the tip, while the shaft slips inside the "skin". On the flank zone, the "skin" remains clings to the external material avoiding slippages and backward movements of the device.

The "skin" movement is driven by a pulling cable, which is actuated by a rotary motor placed on the top of the shaft. The pulling cable is connected to a rigid ring, which can slide on the shaft and pull up the "skin" fixed on it.

In the presented device, while the "skin" is moving up, the hollow shaft is moving down in the opposite direction to the "skin". Since the outside "skin" is anchored to the substrate/walls, the shaft also penetrates the external environment. The surface quality of the "skin" plays a key role for providing a proper anchorage to the soil. For this aim some artificial hair-like structures, which mimic the function of the root hairs, can be added on the "skin". These hairs can rise the static frictional resistance by increasing the interaction with the grains of the substrate.

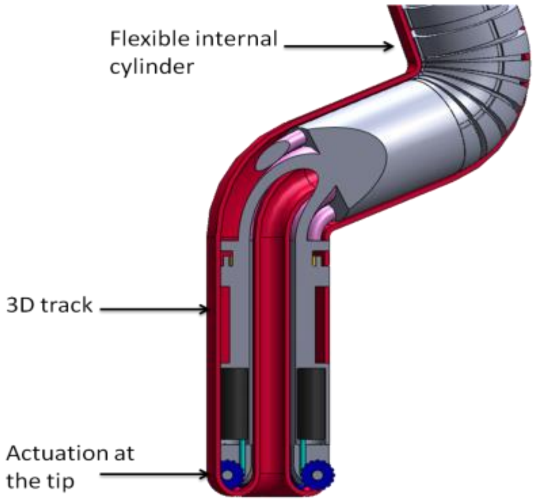

Figure 6. Schematic representation of the device in a bended configuration

In another configuration, the hollow shaft could also be flexible and organized as a segmented structure comprising a proper number of joints that link linear tubular segments. This feature allows the system to change its direction of penetration navigating around the obstacles. The "skin" is still able to move along the bended shaft thanks to a wheel-based mechanism actuation.

Drilling and excavation devices available on the market are based on conventional techniques that need high axial forces in order to perform the penetration process. In simple environments these forces are provided by the weight of the device itself, however, in some conditions, this constraint is not sufficient or not acceptable. Although some non-conventional machining techniques based on lasers or ultrasounds exist on the market, they suffer a high power consumption during the drilling process. The device described above overcomes such limitations providing a robotic mechanism, inspired by plant roots, capable of implementing a non-destructively penetration into structured environments (i.e. pipes) and unstructured environments (i.e. soil, debris, caves, orifices and soft tissues).

Interlaced robot

The device represents a 3D steerable mechanism, composed by two interlaced continuum robots, that advances over a chosen smooth trajectory with an intrinsic follow-the-leader strategy. The track-building is achieved by an alternating method; in every advancing step each continuum robot is alternatively stiffened to guide the other and loosened to be guided, without any further physical supports from the working environment.

The two interlaced continuum robots (CRs) are concentrically located and angularly shifted. Each CR can slide on the other. During the probe deployment the second robot (CR2) systematically follows the first one (CR1); hence, CR1 acts as 'leader' and CR2 as 'follower'.

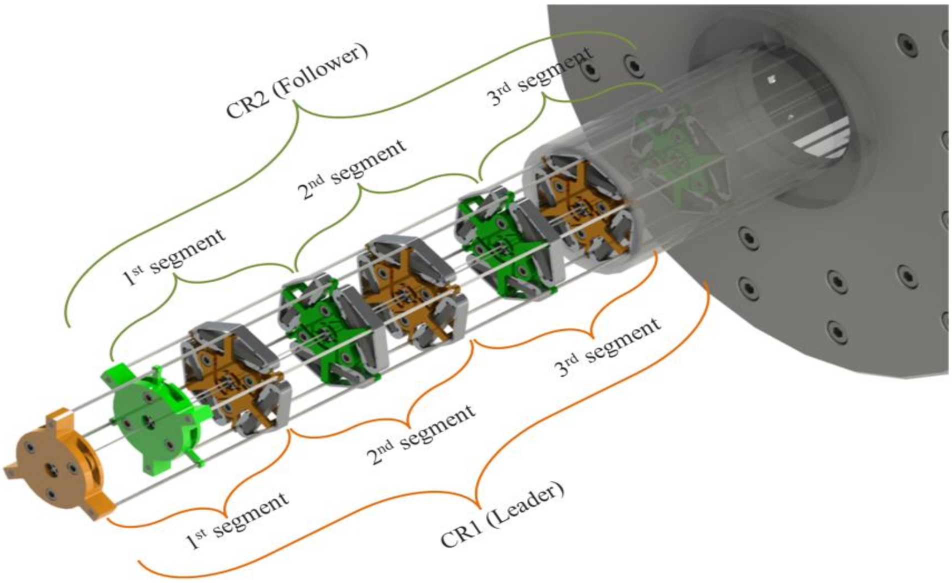

Figure 7. Deployed system

As shown in Figure 7, the system is composed by two identical robots. Each robot comprises:

- a distal element representing the tip of the robot;
- at least three deployment elements;
- a given number of “shape locking” elements;
- at least one connecting element.

The deployment/retrieval movement of the devices is achieved by pushing or pulling the flexible deployment elements. These elements are symmetrically arranged around the ideal central axis of the CR. Steering is achieved by differential pushing/pulling, therefore at least three deployment elements are needed to achieve a complete 3D movement.

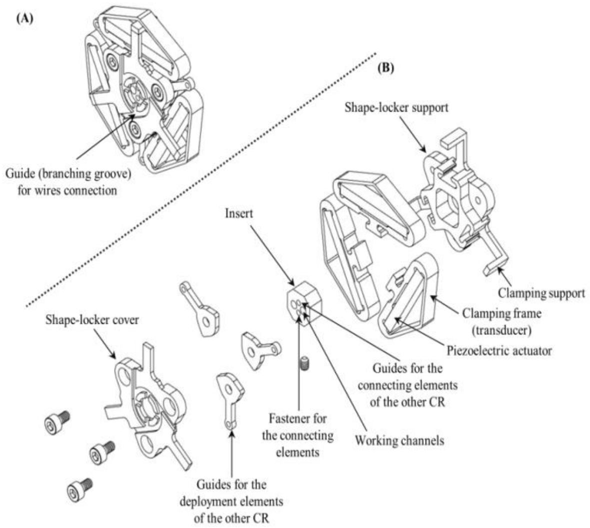

Figure 8. Shape locking element (A) Prospective view (B) exploded view

The shape locking element is the core of the device. This component is designed in order to maintain at the same time a continuum interlaced structure and the clamping capability. This element, which has to be rigid and very thin, is based on piezoelectric actuation. Upon the application of a proper voltage, the elongation of linear piezoelectric actuators is transduced so as to clamp the deployment elements in correspondence of the active interfaces (see Fig. 8).

The stiffening or the loosening of the device is achieved by actively controlling these shape-locking elements. Each segment of the two robots is delimited by two shape-locking elements, except the distal segment that is defined by the distal element and one shape-locking element.

The medical and inspection active devices available in the market are usually based on articulated structures. The restrictions introduced by the segments and joints angle constraints, reduce the accuracy with which the probe can conform to a sought trajectory. On the contrary the robot developed at IIT being based on a continuum structure overcomes these drawbacks. Moreover, the proposed mechanism could be advantageous in view of miniaturization and scalability because the clamping elements are the only active key components that need to be on-board. These elements are obtained through scalable technologies; therefore the proposed concept could be more easily down-scaled than complex articulated systems also featuring on-board mechanics and electronics. Moreover the IIT interlaced robot present a better scaling, in terms of increasing the number of controlled flexible segments, when compared with active continuum probes available on the market.

MARKET ANALYSIS

Based on IIT technologies described in the previous paragraphs, three different markets namely **Environment analysis, endoscopy and non-destructive inspection** have been identified as the major reference marketplaces. Thus, the three markets cited above have been analyzed for their current dimensions and the future trends through a web search based retrieval of specific information. Key players in each market have been then identified and reported with the related websites.

Environmental analysis

According to a report published by marketsandmarkets.com titled "*Environmental Monitoring Market by Product (Monitors, Sensors, and Software), Application (Air, Gas, Water, Soil, and Noise Pollution) and by Region - Global Trends and Forecasts to 2020*", the global environmental monitoring market is positioned to grow at a CAGR (*Compound Annual Growth Rate*) of 7.5% during 2015-2020, and is expected to reach a value of $20.5 Billion in 2020. Although the mature markets (such as the U.S., Germany, France, and U.K.) hold larger shares in the environmental monitoring market, the Asia-Pacific region is expected to grow at the highest CAGR in the forecast period. The growth of the environmental monitoring market is driven by factors such as growing global population, development of policies and initiatives aimed to reduce air, soil, and water pollution, increasing government funding towards pollution prevention and control, growing construction of environmental monitoring stations, growing initiative towards the development of environment-friendly industries, and reduction in export tariff on environmental monitoring technologies in emerging and developed markets.

The emerging markets including China, India, Brazil, and Mexico have become attractive destinations for companies engaged in the development and distribution of environmental monitoring products. A large number of factors such as continuous expansion of oil and gas industry and development of nanotechnology-based environmental monitoring products are offering high growth opportunities for the players' active in the market.

According to the same report, on the basis of type of products, the global environmental monitoring market has been divided into three major segments, namely, environmental monitors, environmental sensors, and environmental software. The environmental monitors segment was expected to account for the largest share of the global environmental monitoring products market, in 2015. Furthermore, environmental sensors segment is expected to grow at the highest CAGR in the next five years, owing to factors such as growing use of a particular sensing device into various applications, and growing trend towards miniaturization of sensors during the study period. On the basis of type of application, the global market is classified into air pollution, water pollution, soil pollution, and noise pollution monitoring (see Fig. 9 Source: Technavio, 2015)

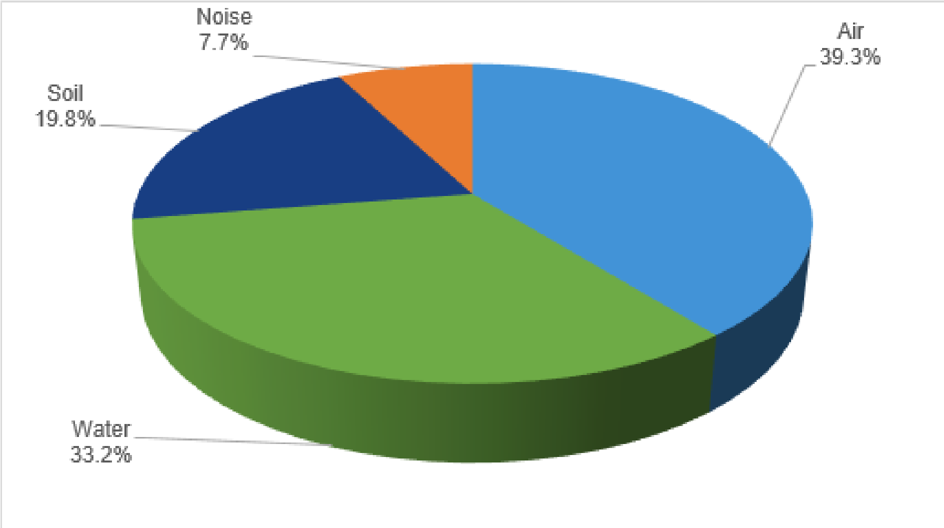

Figure 9. Global environmental sensing and monitoring market segmentation by application 2019

The soil segment, which represents the 19.8% of the overall market includes applications like monitoring ecosystem and bio-complexity, mapping forest landscapes, detecting land use, landslide, and agricultural patterns, seismic sensing and situational awareness.

Inside this market, bio-inspired sensors are gaining a big relevance; these type of products are inspired from natural/biological processes, this new breed of sensor is pushing current IT technology to new standards.

In this perspective, the technology developed at IIT represents a key example on how the technology could be bio-inspired in order to obtain more efficient systems that are at the same time environmental friendly and adaptable to different type of sensing. Thanks to the static approach with the surrounding substrate and thanks to the internal hollow structure, that is maintained during the drilling operation, different type of sensors could be inserted inside the proposed devices even during operative conditions.

A large slice of the global environmental monitoring market is represented by the soil moisture sensor market. According to the report published by marketandmaarket.com and titled *"Soil Moisture Sensor Market by Type (Volumetric and Water Potential), Application (Agriculture, Residential, Landscaping, Sports Turf, Weather Forecasting, Forestry, Research Studies and Construction), & Geography - Global trends & Forecast to 2020"*, soil moisture sensors, used to monitor the moisture content in the soil, are very helpful in protecting water resources and understanding the ever-changing climate. With the demand for reduction in critical water resource, the soil moisture sensors market is expected to have a wide scope of applications in areas such as agriculture, residential, landscaping and ground care, sports turf, weather forecasting, forestry, research studies, and construction. The growth of the soil moisture sensor market is driven by gradual shift in the climatic conditions, environmental regulations, and improved productivity. As shown in the graphic below (Fig.10 marketsandmarkets Soil Moisture Sensor Market by Type (Volumetric and Water Potential), Application (Agriculture, Residential, Landscaping, Sports Turf, Weather Forecasting, Forestry, Research Studies and Construction), & Geography - Global trends & Forecast to 2020), the market is estimated to reach USD 206.2 Million by 2020, at a CAGR of 16.2% between 2015 and 2020.

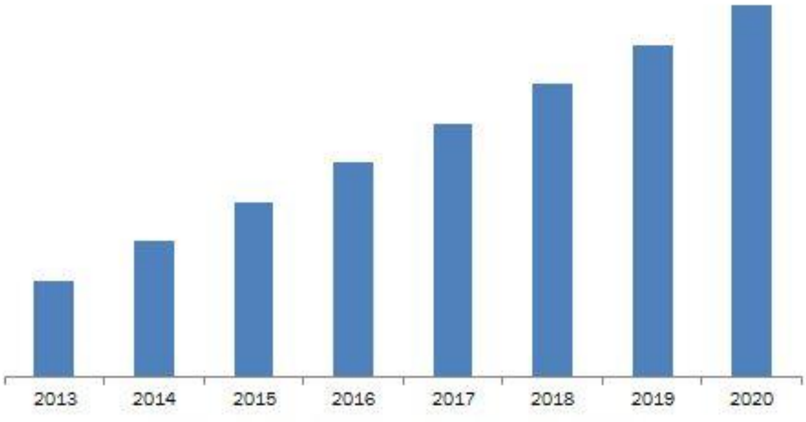

Figure 10. Growth of soil sensors market 2013-2020

The technology developed at IIT could enter this market being coupled with these sensors in order to bring them at different soil level, allowing a larger number of measurements without destroying the examined substrate during the effective use of the moisture sensor embedded into the bio-inspired robot.

The Americas accounted for a large market share followed by Europe and APAC in 2014. The market in APAC is expected to grow at the highest rate during the forecast period. The Rest of World which includes the Middle East and Africa accounts for a small market share at present; however, it is expected to grow during the forecast period due to the increasing requirement of soil moisture sensors in this region.

Endoscopy inspection

According to the report by Transparency Market Research, titled *"Endoscopy Devices Market - Global Industry Analysis, Size, Share, Growth, Trends and Forecast, 2013 - 2019"*, the minimally invasive characteristics of endoscopes and their use in many surgical and diagnostic procedures will play a pivotal role in the growth of the global endoscope devices market in the coming years. This report, which analyses the market by device type, areas of application, and geography, states that the market was valued at US$24.9 billion in 2012 and is further expected to reach an approximate value of about US$36.9 bn in 2019, rising considerably from its 2012 valuation. This translates to a CAGR of 6.8% between 2013 and 2019.

The demand from this market has also increased due to the reduced chances of infection and blood loss during the surgical operation as a result of non-invasive procedures and shorter stay at hospitals because of a quicker recovery that in turn generates a reduced cost for the society. These factors are advantageous in the field of medicine, especially oncology. Hence, the adoption of endoscopy is increasing rapidly across major regions in the world. The global endoscopy devices market is categorized by two key criteria – device type and application. Based on the device type, the endoscopy market comprises endoscopes, operative devices, visualization systems, and high-definition (HD) visualization systems. The visualization systems segment further includes image processing devices, display, camera, control unit, and illumination devices, whereas other specialized operative instruments include internal closure devices, energy systems, irrigation systems, and others (see Fig.11 transparencymarketresearch [Endoscopy Devices Market - Global Industry Analysis, Size, Share, Growth, Trends and Forecast, 2013 - 2019])

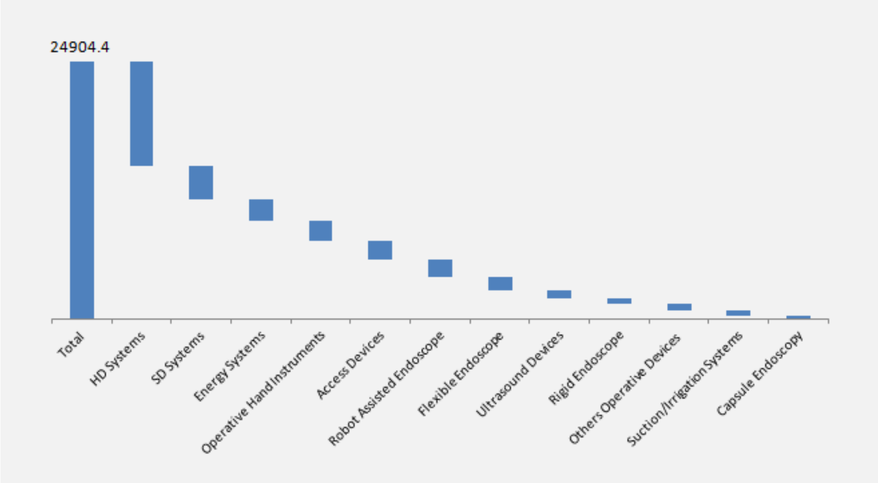

Figure 11. Global endoscopy devices market, by device type, 2012 (USD Million)

Several types of endoscopy devices are present into the market, among them robot-assisted endoscopes have completely transformed the endoscopy market. Due to these effective devices, the diagnosis of body internal conditions has become more efficient and accurate. One of the leading market players, Given Imaging, which was acquired by Covidien-Medtronic in 2014, accounts for nearly 85% of the global capsule endoscopy market. Other key players in the capsule endoscopy market are, Olympus, and IntroMedic. Visualization systems have also witnessed significant technological advancements in the recent past. The development of three-dimensional (3D) camera systems has reduced the errors and improved depth perception during surgical procedures, hence reducing the overall surgery time. Similarly, endoscopic ultrasound devices allow doctors to effectively diagnose intestinal tract conditions and obtain more accurate images, allowing more detailed and thus more precise examination of the same.

The technology developed at IIT, thanks to its peculiar characteristics of non-destructive approach with surrounding environments and to its hollow structure that is maintained during the penetration could be used as tool/endoscope guide, to be adapted to all the previously mentioned different categories and thus attractive for a variety of companies active inside the endoscopy market.

According to another report published by marketandmarket.com and titled *"Endoscopy Equipment Market by Product (Endoscopes (Flexible, Rigid, Capsule), Visualization Systems, Other Endoscopy Equipment (Electrical, Mechanical), Accessories), by Application (Laparoscopy, Bronchoscopy, GI Endoscopy) - Trends & Global Forecasts to 2020"*, the North America endoscopy devices market was the largest in the world as of 2012 thanks to the presence of advanced healthcare facilities, higher adoption of advanced diagnostic and surgical devices, well-trained endoscopy professionals, heightened awareness among patients, favorable reimbursements, increasing incidences of cancer in the US and Canada, research on new technologies in the US and new funding model for Canadian hospitals. However, as shown in the graph below (Fig. 12, marketsandmarkets Endoscopy Equipment Market by Product (Endoscopes (Flexible, Rigid, Capsule), Visualization Systems, Other Endoscopy Equipment (Electrical, Mechanical), Accessories), by Application (Laparoscopy, Bronchoscopy, GI Endoscopy) - Trends & Global Forecasts to 2020) APAC market is slated to grow at the highest CAGR during the forecast period if compared to the other two main markets. It serves as a revenue pocket for companies offering endoscopy equipment.

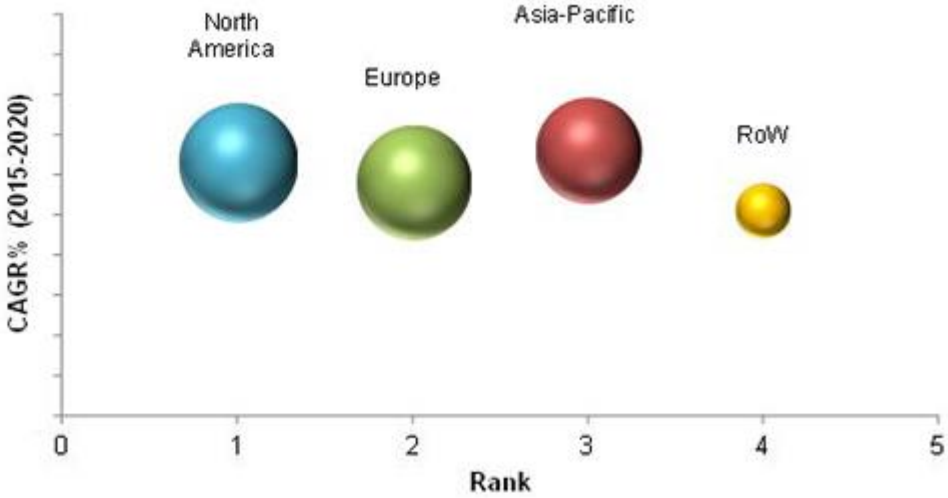

Figure 12. Global endoscopy market size by region, 2015-2020. The size of the bubble chart depicts the market size (USD billion) in 2015

Accordingly to this report, in the coming years, the endoscopy equipment market is expected to witness the highest growth rate in in India, China, and Japan. The high growth in India and China can be attributed to government investments in establishing new endoscopy units in India and government and venture capital investments in China. North America is expected to account for the largest share of the global market.

Non-destructive Inspection

According to the report published by marketandmarket.com and titled "Non-Destructive Testing and Inspection Market by Technique (Visual Testing, Magnetic Particle, Liquid Penetrant, Eddy Current, Ultrasonic, Radiographic, Acoustic Emission, Terahertz Imaging), Service, Vertical, and Geography - Global Forecast to 2022", the non-destructive testing (NDT) market is expected to reach USD 11.39 Billion by 2022 at a CAGR of 8.30% between 2016 and 2022. NDT assures safety and reliability by identifying flaws and defects in products without disrupting operations or delaying processes. Non-destructive testing has its applications in various industries such as aerospace & defense, automotive, oil & gas, infrastructure, and power generation. The report provides a description of each of the application areas of non-destructive inspection market. The market within this study has been classified on the basis of NDT technique into visual inspection testing, magnetic particle testing, liquid penetrant testing, Eddy current testing, ultrasonic testing, radiography testing, acoustic emission testing, and terahertz imaging.

Ultrasonic testing is expected to hold the largest market share between 2016 and 2022. Ultrasonic testing is a fast, reliable, and versatile method of inspection. It detects internal and hidden discontinuities. Ultrasonic rays have high penetrating power, sensitivity, and accuracy; also, they are non-hazardous.

The technology developed at IIT could serve as a vector for automatically bringing all the sensor inside the inspected environment avoiding damages generally caused by the passage of the common probes used for non-destructive testing until now.

The vertical application in the oil & gas is expected to hold the largest market share between 2016 and 2022. The demand for testing in this sector is largely driven by mandates by various governments for ensuring the safety of the environment by avoiding pipeline leakages, oil spills, and other accidents. The market for the vertical manufacturing is expected to grow at a highest rate between 2016 and 2022.

North America held the largest share of the NDT market in 2015, and it is expected to grow at a moderate CAGR between 2016 and 2022. The market in APAC is estimated to grow at the highest rate during the forecast period (see Fig. 13 marketsandmarkets Non-Destructive Testing and Inspection Market by Technique (Visual Testing, Magnetic Particle, Liquid Penetrant, Eddy Current, Ultrasonic, Radiographic, Acoustic Emission, Terahertz Imaging), Service, Vertical, and Geography - Global Forecast to 2022). The demand for non-destructive testing in the APAC region is expected to be driven by increasing infrastructure projects and power plants.

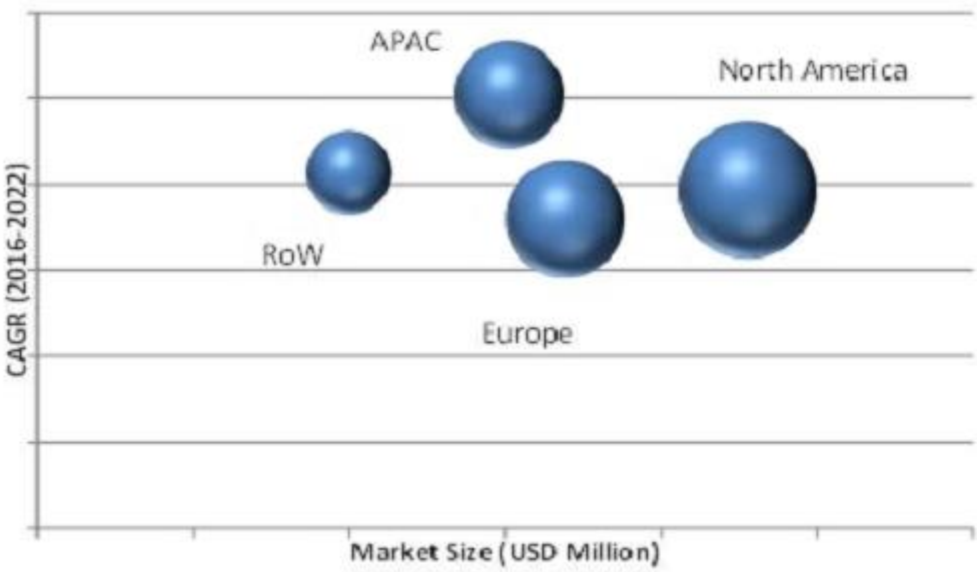

Figure 13. NDT market size, by region, 2015 (USD million)

There are few restraints for this market such as the high cost of automated NDT equipment and the lack of skilled and qualified personnel. The setup cost is high for automated equipment. As a result of which, many small scale organizations use simple inspection systems which might not be as reliable as the automated ones. Also, the lack of awareness about new technologies and less number of training centers are hampering the NDT market growth.

According to another report, published by strategyr.com on January 2015 and titled: "The global Nondestructive Test Equipment Market Trends, Drivers & Projections", the global NDT equipment market is projected to reach US$1.8 billion by 2020, driven by the introduction of automated, technologically advanced, user-friendly equipment. Other factors driving growth in this market include increasing complexity of machines, high cost of machinery failure, stringent product usage specifications and tight quality control requirements (see Fig. 14 strategyr The global Nondestructive Test Equipment Market Trends, Drivers & Projections). As a method of testing materials and components for identifying defects, NDT equipment is finding widespread applications in range of end-use sectors. Petrochemical, aviation and manufacturing industries represent a few of the key application areas.

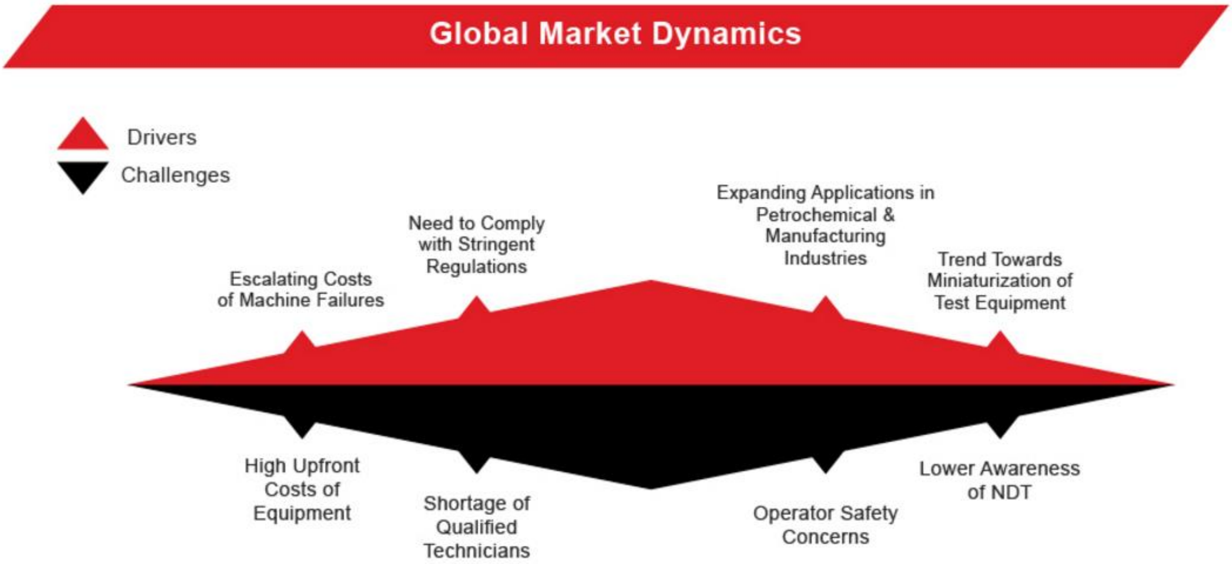

Figure 14. Global NDT market dynamics: drivers and challenges

Ultrasonic and eddy-current testing equipment represent traditional product markets which have achieved tremendous success over the years. Future growth, however, is forecast to come from emerging new technologies such as X-Ray computed tomography, phased array ultrasonic and computed radiography. Remote visual inspection equipment is also achieving considerable attention with the aerospace sector especially mandating use of this equipment in a wide range of applications.

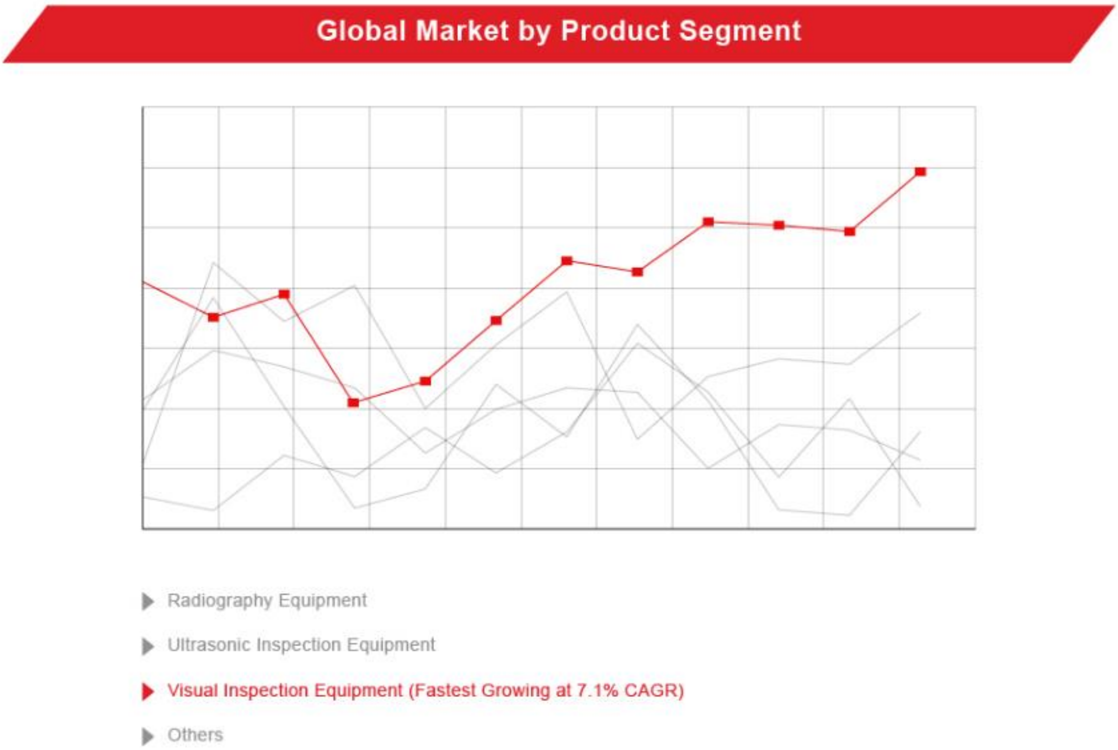

Figure 15. Global NDT Inspection market by product segment

As shown in the graph above (Fig. 15 strategyr The global Nondestructive Test Equipment Market Trends, Drivers & Projections), the Visual inspection equipment is the fast growing sector with a CAGR of 7.1% in the considered period.

According to the report, Europe represents the largest regional market worldwide. APAC region is the fastest growing market with a projected CAGR of 10% over the analysis period. Demand in the region is led by establishment of new power and transportation infrastructure and rapid growth in automotive production bases in countries such as china and India.

The technology developed at IIT can be fully automated and does not require any particular qualification thanks to its ease of use. Coupling the sensors used for the non-destructive inspection with the above presented technology it's possible to overcome the market restraints highlighted in the mentioned reports. The presented devices, are not only easy to use but also have a lower cost if compared to actual automated NDT systems.

COMPETITIVE SCENARIO

The main advantages of IIT's bio-inspired robots in comparison with the conventional penetration and inspection techniques have already been discussed in previous paragraphs: the shown devices provide non-destructive, automatic and easy operations while maintaining a hollow structure.

Being inspired by nature, they represent a unique approach in the fields of environmental analysis, endoscopy and non-destructive inspection. The IIT's systems could also overcome several drawbacks still present even in the current non-conventional machining techniques. The major issues to be faced with current instruments are the following:

1. integrity of the sample
2. compactness of the system
3. high axial forces
4. high power consumption

IIT's devices offer a solution to all of these issues thanks to their particular structure inspired from the nature.

In the following lists we have considered the major key players divided into the three areas of interest identified in the market analysis paragraph. For each area the companies have been divided for geographical location.

Key players and major companies in the sector of environmental analysis in Italy

- Pedonlab (http://www.pedonlab.it/)
- Centro Analisi Chimiche (http://www.centroanalisichimiche.it/)
- Pagani Geotechnical Equipment (http://www.pagani-geotechnical.com/index.php/en/)
- Boviar (http://www.boviar.com/)
- Sisgeo (http://www.sisgeo.com/)
- GD Test (http://www.gdtest.it/)
- Massenza Drilling Rigs (http://www.massenzarigs.it/)
- Simam (http://www.simamspa.it/)
- Fraste (http://www.fraste.com/it/)
- Italsonda (http://www.italsonda.net/)
- Geotech (http://www.geotecspa.com/index.php?lang=en)

Key players and major companies in the sector of environmental analysis in the world

- TE Connectivity (Switzerland, http://www.te.com/usa-en/home.html)
- Delta T Devices (United Kingdom http://www.delta-t.co.uk/)
- Siemens AG (Deutschland https://www.siemens.com/global/en/home.html)
- Thales Group (France https://www.thalesgroup.com/en)

- Agilent Technologies (U.S.A. http://www.agilent.com/home)
- Danaher Corporation (U.S.A. http://www.danaher.com/)
- ESI Environment Sensor (Canada http://www.esica.com/)
- Honeywell International (U.S.A. http://www.honeywell.com/)
- Ball Aerospace and Technologies Corporation(U.S.A. http://www.ball.com/aerospace)
- The Raytheon Company (U.S.A. http://www.raytheon.com/)
- Decagon Devices (U.S.A. http://www.decagon.com/en/)
- The Toro Company (U.S.A. http://www.thetorocompany.com/)
- Irrometer Company (U.S.A. http://www.irrometer.com/)
- Sentek (Australia http://www.sentek.com.au/)
- AquaCheck(U.S.A. http://www.aquachecktech.com/)
- Stevens (U.S.A. http://www.stevenswater.com/)
- Rainbird (U.S.A. http://www.rainbird.com/)

Key players and major companies in the sector of endoscopy in Italy

- Centro Elettromedicali (http://centrel.com/it/)
- Multimage (http://www.multimage.biz/)
- Medi Line (http://www.mediline.eu/)

Key players and major companies in the sector of endoscopy in the world

- Sanofi (France http://en.sanofi.com/)
- Contact Co (Ukraine http://www.contact-endoscopy.com/)
- Purple Surgical (United Kingdom http://www.purplesurgical.com/uk/)
- Vimex (Poland http://vimex-endoscopy.com/)
- Philips Healthcare (Netherlands www.healthcare.philips.com)
- Ambu A/S (Denmark http://www.ambu.com/)
- Siemens Healthcare Gmbh (Deutschland http://www.healthcare.siemens.it/)
- B Braun (Deutschland https://www.bbraun.com/en.html)
- Maquet Holding B.V. & Co. (Deutschland http://evh.maquet.com/)
- Gimmi Gmbh (Deutschland http://www.gimmi.de/)
- Karl Storz GmbH & Co. KG (Deutschland https://www.karlstorz.com/it/it/index.htm)
- W.O.M. World Of Medicine GmbH (U.S.A. http://www.world-of-medicine.com/en.html)
- Cook Medical (U.S.A. https://www.cookmedical.com/)
- Abbott (U.S.A. http://www.abbott.com/)
- Pentax Medical (U.S.A. https://www.pentaxmedical.com/pentax/)
- Medtronic (U.S.A. http://www.medtronic.com/)
- Medi-Globe Corporation (U.S.A. http://www.mediglobe.com/)
- Stryker (U.S.A. http://www.stryker.com/)
- Fujifilm (Japan http://www.fujifilm.com/)
- Olympus Corporation (Japan http://www.olympus-global.com/)

- Hitachi (Japan http://www.hitachi.com/)
- Intromedic (Korea http://www.intromedic.com/eng/)

Key players and major companies in the sector of Non-destructive inspection in Italy

- Beta Utensili (http://www.beta-tools.it/beta/index.html)
- NDT Italiana (http://www.ndt.it/)
- Fort Fibre Ottiche (http://www.fort.it/)
- CGM Cigiemme (http://www.cgm-cigiemme.it/)
- DRC Italia (http://www.drcitalia.it/)
- Bosello High Technology (http://www.bosello.eu/it/)
- FCA Group (http://www.fcagroup.com/it-it/pages/home.aspx)
- Ferrari (http://www.ferrari.com/it_it/)
- Lamborghini (http://www.lamborghini.com/en/home/)
- Piaggio Aerospace (http://www.piaggioaerospace.it/it)
- Leonardo (http://www.leonardocompany.com/)
- Alitalia Servizi (http://www.flyalitalia.com/en/services/manutenzione.htm)
- Meridiana Servizi (http://www.meridianamaintenance.com/it-it/home.aspx)
- Aris (http://www.aris-spa.it/)
- Altec (https://www.altecspace.it/)
- Saipem (http://www.saipem.com/sites/SAIPEM_it_IT/home/saipem-homepage.page)

Key players and major companies in the sector of Non-destructive inspection in the world

- Ashtead Technology (United Kingdom http://www.ashtead-technology.com/)
- Sonatest (United Kingdom http://sonatest.com/)
- BAE Systems (United Kingdom http://www.baesystems.com/en/home)
- Airbus (France-Europe http://www.airbus.com/)
- Yxlon (Deutschland http://www.yxlon.com/Home)
- Transocean (Switzerland http://www.deepwater.com/)
- SGS (Switzerland http://www.sgs.com/)
- Fltechnics (Lithuania http://www.fltechnics.com/)
- General Electric (U.S.A. http://www.ge.com/)
- Mistras (U.S.A. http://www.mistrasgroup.com/)
- Nikon Corporation (Japan http://www.nikon.com/)
- Magnaflux (U.S.A. http://www.magnaflux.com/)
- Zetec (U.S.A. http://www.zetec.com/)
- Sonotron (Israel http://www.sonotronndt.com/)
- Fischer Technology (U.S.A. http://www.fischer-technology.com/en/us/home/)
- Eddyfi (Canada http://www.eddyfi.com/)
- Lockheed Martin (U.S.A. http://www.lockheedmartin.com/)
- Boeing (U.S.A. http://www.boeing.com/)

- Northrop Grumman (U.S.A. http://www.northropgrumman.com/)
- UTC (U.S.A. http://utcaerospacesystems.com/Pages/Default.aspx)
- Schlumberger (U.S.A. http://www.slb.com/)
- Halliburton (U.S.A. http://www.halliburton.com/en-US/default.page)
- Baker Hughes (U.S.A.   http://www.bakerhughes.com/)
- Fluor (U.S.A. http://www.fluor.com/pages/default.aspx)

FOR FURTHER READING

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