Applications of robotic technologies in the upstream and downstream sector

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1. Theme Description

According to the 2017 edition of the BP Energy Outlookthe world economy will double over the next 20 years with an annual growth of 3,4% drive by China and India. Oil, gas and carbon will account for more than 75% of energy supplies in 2035, despite of the use of renewable resources will increase. In this context gas will overtake coal becoming the second fuels source in 2035 with an annual growth of 1,6 %.[1]Focus on oil demand, it reached 94,4 Mbbl/day in 2015 and it is expected to overtake 100 Mbbl/day in 2021.[2]Therefore oil companies have started to explore new unconventional reservoirs such as tight and heavy oil, shale gas etc. with the aim to increase the production.[3] However these new oilfields are in desert, artic, deep water zones and require specific technologies to be extracted. In last fifty years several accidents occurred such as Exxon Valdez oil spill in 1989[4]or Deepwater Horizon oil spill in 2010[5]. In this scenario robotic technologies can have a key role in increasing safety, efficiency, productivity and minimize risks. Therefore, in the following sections their applications in the oil and gas sectors are described.

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[1]https://www.bp.com/content/dam/bp/pdf/energy-economics/energy-outlook-2017/bp-energy-outlook-2017.pdf

[2]https://www.iea.org/publications/freepublications/publication/MTOMR2016.pdf

[3]http://www.unconventionalenergyresources.com/

[4]https://www.britannica.com/event/Exxon-Valdez-oil-spill

[5]https://www.britannica.com/event/Deepwater-Horizon-oil-spill-of-2010

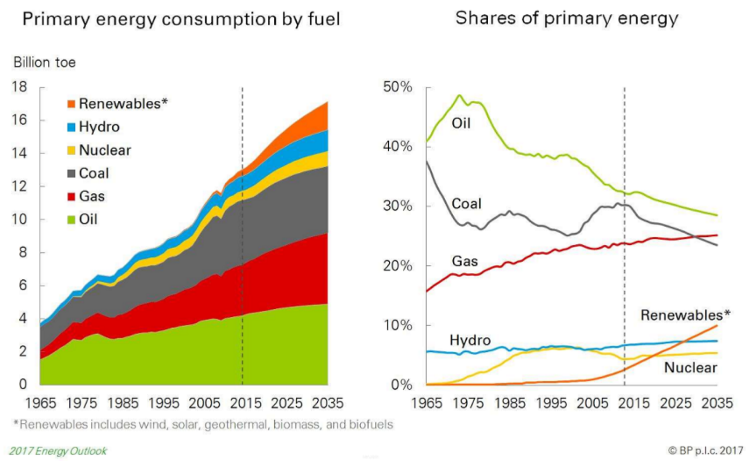

Figure 1 - Energy Consumption from 1965 up to 2035.

2. Robotic Applications

Robotic technologies can transform oil and gas sector. Today robots can execute single operation and are controlled by skilled operator, but in the future, they could take multiple actions autonomously, replacing workers on field. In this section the main applications in the oil and gas sector are described.

Unnamed Vehicle: ROVs, AUVs and UAVs

Recently, robots, such as unmanned vehicles, have been used in deep water applications, pipeline inspection,surveillance of product plants etc.,to reduce accidents and increase safety for human and marine lives.The first vehicles were launched in 1950 by Ryan Aeronaticalfor military reconnaissance and then, in the 1960-1970s, the US Navy tested theCable-Controlled Underwater Recovery Vehicles (CURV, CURV II and CURV III).Since 1980 these robots have been used in the oil and gas sectors and nowadays can be divided into three categories: Remotely Operated Vehicles (ROVs), Autonomous Underwater Vehicles (AUVs) and Unnamed Aerial Vehicle (UAVs).[6,7]

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[6] https://www.researchgate.net/publication/282422353_Application_of_robotics_in_onshore_oil_and_gas_industry-A_review_Part_I

[7] http://www.mdpi.com/2077-1312/5/1/13

ROVs are equipped with video camera, lights and articulating arms to grab samples to study, cut lines etc. These vehicles, connected to a ship by cables, are driven remotely by an operator.ROVs can be used for geophysical survey, indeed, equipped with multi-beam echo sounders (MBES) and side-scan sonar (SSS) can create images of geological formations. Furthermore, theserobots canbe used for drilling assistance, indeed, when a new reservoir is discovered sample of rocks are collected to analyses the characteristics of fluids and several wells are necessary to understand the extension of the basin. ROVs can be used for measuring the alignment and penetration of the suction anchor of the drill ship. Other applications involve maintenance, repair and inspection of underwater structures to prevent corrosion, fractures and failure by fatigue [8]. For more information about ROVs can be consulted*R. D Christ and R. L. Wernli, Sr.*[9]While, **AUVs** are usually torpedo-shaped robots deployed from a surface vessel. They work independently from the ship for periods of hours up to days, indeed they don't require operator intervention. Thesevehicles are suitable for hazardous environments such as polar regions, can work up to depth of 6000 m and their speed mobility and spatial range are greater than ROVs.[10]For more information about AUVs can be consulted *Griffith*.[11]

UAVs, instead, can be used for leaks detections, damage of structures and in the conflict areas such as Angola, Nigeria etc. Usually, pipeline inspections are performed by a group of workers or sometimes by a network of sensors that measure flow, temperature, pressure, transmitting collected data to control room. However, this system is weak of failure and can provide incomplete information. Therefore, to prevent accidents and improve the quality of the maintenance several projects have been launched in last years. Two of them involved British Petroleum (BP) in collaboration with AeroVironment and the University of Alaska Fairbank. In the first project **Puma™AE** platform was used in the Prudhoe Bay (Alaska) to inspect deteriorated infrastructure and areas vulnerable to flood. The vehicle was equipped

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[8] https://www.researchgate.net/publication/282423814_Application_of_robotics_in_offshore_oil_and_gas_industry-A_review_Part_II

[9] R. D. Christ and R. L. Wernli, Sr, *The ROV Manual: A User Guide for Remotely Operated Vehicles, A User Guide for Remotely Operated Vehicles*, Second Edition, Butterworth-Heinemann 2014

[10] https://www.researchgate.net/publication/260998128_Autonomous_Underwater_Vehicles_AUVs_Their_past_present_and_future_contributions_to_the_advancement_of_marine_geoscience

[11] Griffiths, G. (Ed.). (2002). Technology and Applications of Autonomous Underwater Vehicles. London: CRC Press.

with LiDAR or EO/IR sensors and allowed to create 3D images of the area. In the second project the **AeryonScout™**, equipped with high-resolution and IR cameras, flowbelow 150 m of altitude allowing to identify hotspots by means of thermal images. Other two applications involve Conoco Phillips-Boing and Aeronautic. The first **ScanEagle® X200**, a waterproof vehicle equipped with EO/IR sensors, was used in the Chuckchi Sea (Northwest of Alaska) to monitor mammals marine and ice areas by means of real-time video. The last represented by Aerostar®,equipped with IR camera was used in Angola to control offshore oil fields by means of differential thermal imaging allowing to detect leaks in buried oil and water pipelines.[12]

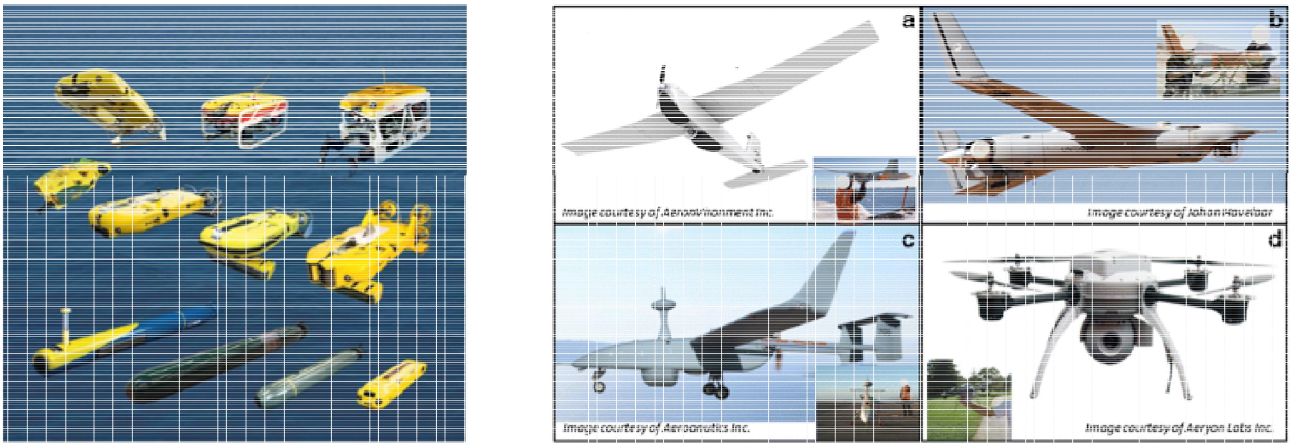

Figure 2 -On the left side are shown the main ROVs and AUVs commercially available; on the right side are sketched the four UAVs involved in the oil and gas pipeline monitoring: a) Puma™ AE b) ScanEagle® X200 c) Aerostar® d) Aeryon Scout™.[8,12]

Pipe inspection: IPRs

In-Pipe Inspection Robots (IPIRs), equipped with camera, sonar, acoustic detector, LED light panel etc., are used for Non-destructive Tests (NDT) such X-ray, ultrasonic and eddy currents tests. They can be divided into three main categories: Wheel, Caterpillar and Without Wheel Type Robots. In the first case, wheelsare directly connected to motor, or mounted to the elastic arms (wheeled wall pressed). Screw type robots fall in this category. They are formed by two elements: a rotor composed by three inclined wheels that transform the rotative of motor into translation motion anda stator formed by straight wheels that give stability to the structure. Caterpillar type robot, instead, is formed by belt that surrounded wheels

[12]Gómez, C. & Green, D.R. Arab J Geosci (2017) 10: 202. https://doi.org/10.1007/s12517-017-2989-x

allowing robot to move through even surface, climb vertical and inclined pipe. The non-wheels types instead include robots such as inchworm, snake and leg type.[13]

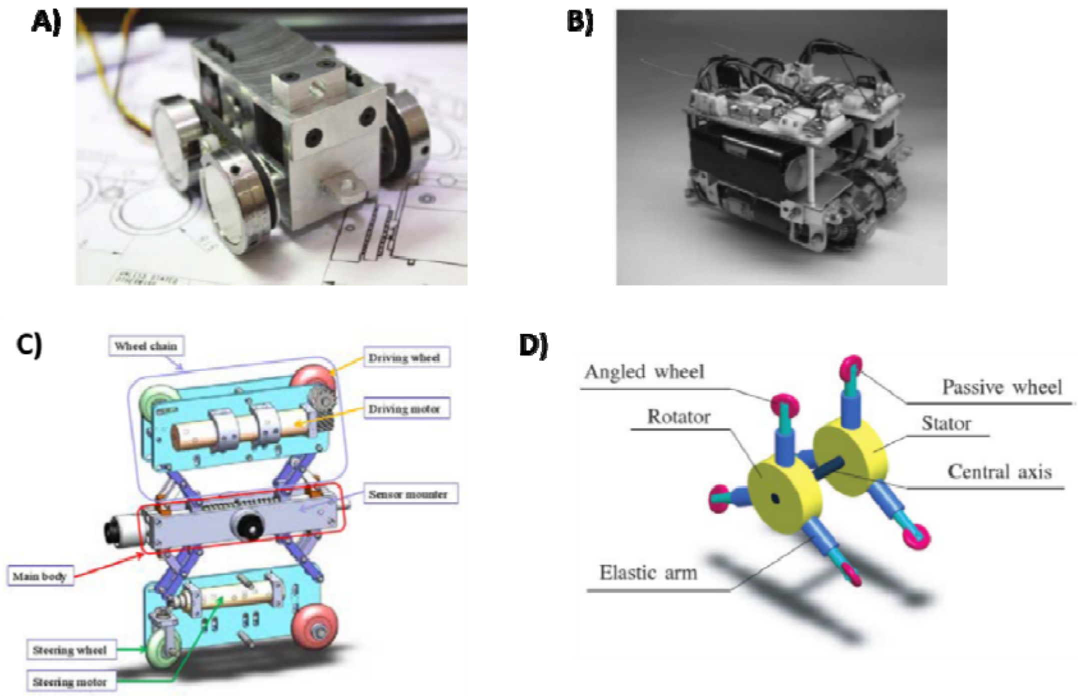

Figure 3 - A) Wheel Type Robot, B) Caterpillar Type Robot, C) Wheeled Wall Pressed and D)Wheeled Wall Pressed Screw Type Robot.[14]

Tank Inspection

Robots can be used also for tank inspections. In this way the production isn't stopped and the tank can be control completely full. There are several kinds of robots divided according to the mechanism of adhesion and locomotion. One of the first tank inspection robot was Neptune developed by Robotics Institute in 1994.

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[13] https://www.researchgate.net/publication/275540925_Design_of_a_New_In-Pipe_Inspection_Robot

[14] M. Han et al., *Analysis of In-Pipe Inspection Robot Structure Design,* 2nd Workshop on Advanced Research and Technology in Industry Applications (WARTIA 2016).

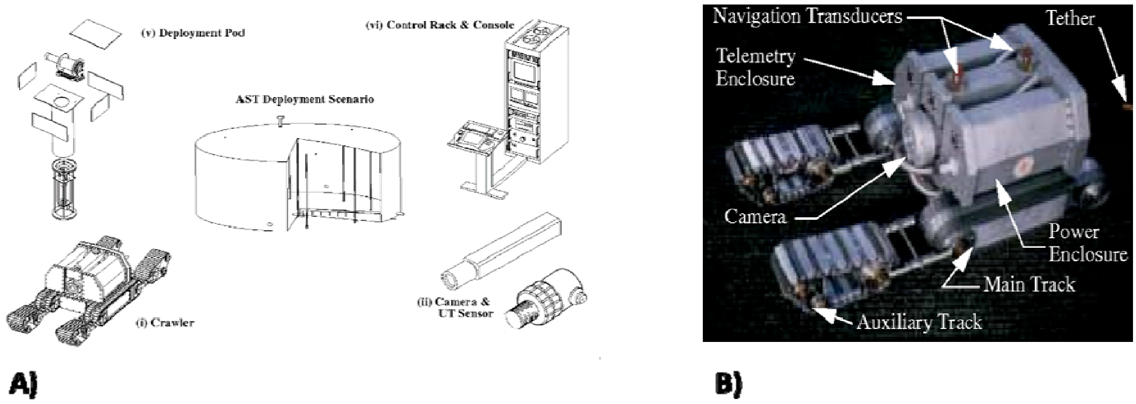

Figure 4 -A) Neptune System, B) Detailed Image of Neptune Robot. [15]

The system consists of a robot crawler, the deployment pod and the remote console for control and display. The robot is equipped with a camera, ultrasonic sensors, onboard control and telemetry system that allows to monitor the state of tank walls (thickness and welded seams).[16]

Gas Sampling

The gas sampling is a common technique in the oil and gas industry to controlthe composition and the quality of the hydrocarbon feedstock. Skilled operator, by means of hand valves, fills high-pressure containers with the gas to be examined. This practice could be very dangerous and samples quality depends on the operator’s ability. Therefore, recently Statoil has tested, on onsite facility, automated gas sampling. The system consists of a 6-axes robot, a sampling station and distributed control system (DCS). The operator, by means of external camera, move the robot, puts the container in the filling dock and open the ball valve. When the filling process is ended the DCS advises the operator that, by means of the robot, close the valve and remove the container for examination.[17]

Automatic Drilling

Drilling operations are expensive and dangerous for environment and workers. It was estimated that there were 1,600 injuries and 18 fatalities in 2014. Recently the Norwegian Robotic Drilling System AS (RDS) has developed, in cooperation with

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[15] https://www.semanticscholar.org/paper/Neptune%3A-Above-Ground-Storage-Tank-Inspection-Robot-Schempf/d4ebb84d574487ac27a907fc5244896aa72ec925

[16] https://pdfs.semanticscholar.org/d4eb/b84d574487ac27a907fc5244896aa72ec925.pdf

[17] V. Kongezos et al., *Human-robot cooperation for error recovery in oil and gas applications*, IET Conference on Control andAutomation 2013: Uniting Problems and Solutions, 2013, pp. 1–6.

Siemens, an automatic system composed by drill floor robots with multi-size elevator, robotic roughnecks and pipe handlers.

Figure 5 - On the left side the RDS's robot, on the right side the SCALNCE X 200 series.18

The robot is equipped with SIMATIC IPC's control system that translate process commands from sensors into a series of movements. The control system is formed by: SINAMICS 120, SIMATIC S7-300 and SIMATIC ET 200 used for frequency converters, as controllers and distribute IO system. Data are visualized and monitored by skilled operator in the control room by means of WinCC Advanced on SIMATIC HMI. The communication between the control room and the robots is ensured by the industrial Ethernet switches SCALANCE S and SCALANCE X range. The system has been testing under real condition in a North America and North Sea near Norwegian coasts. It could reduce rig time per well, operation costs and increase safety. [18]

1. Conclusion

The world economy will double over the next 20 years; oil, gas and carbon will account for more than 75% of energy supplies in 2035. Therefore, new sources will be necessary and unconventional reservoirs will have to be exploited. However, these new oilfields are in desert, artic, deep water zones and require specific technologies to be extracted. Robotic technologies can have a pivotal role in reducing costs and improve quality and safety. The Digital Transformation Initiative (DTI) project has estimated, indeed, that drilling, completion, maintenance andinspection costs will fall down of about 20-25%. Furthermore, in the next 3-5 years robotics and drone

[18] https://www.industry.siemens.com/datapool/industry/automation/Tech-Art/2017/2017_12_31_RDS/Oil_and_gas_drilling_goes_digital_en.pdf

applications will grow of about 15%.[19]Some of the main technologies are described such as Unnamed Vehicle (ROVs, AUVs and UAVs), the In-Pipe Inspection Robots (IPIRs), robots for Tank Inspection (i.e. Neptune) and Gas Sampling (i.e. Statoil project). In this scenario RDS, in cooperation with Siemens, has developed an automatic drilling floor. The system has been tested under real conditions and could reduce rig time per well, operation costs and increase safety.

[19] http://reports.weforum.org/digital-transformation/wp-content/blogs.dir/94/mp/files/pages/files/dti-oil-and-gas-industry-white-paper.pdf