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ANYmal – A unique quadruped robot for hars

In this article, the latest in a series on the development of robotic solutions for difficult environments, Dr. Péter Fankhauser of ANYbotics AG in Switzerland describes the development of ANYmal, built specifically to work autonomously in challenging surroundings.

Inspection and surveillance tasks on industrial sites can be repetitive, dirty and dangerous. The ANYbotics team based in Zurich, Switzerland, has developed a solution to this problem in the form of 'ANYmal'; a unique quadrupedal robot that can perform these roles autonomously, carrying sophisticated sensory equipment to any point of interest. Its unique ANYdrive system provides exceptional mobility and enables the four- legged robot to work in harsh environments.

Mobile machines have always had the potential to support humans in dangerous industrial situations, but only recent advancements in robotics have given them the capacity to do so. The physical layout of industrial sites, consisting of stairs, gaps and other obstacles, adds a layer of complexity, preventing the use of traditionally wheeled or tracked robots. While drones can overcome some of these problems, they cannot operate in bad weather and their payload capacity and energy autonomy can be limiting.

The ANYbotics team has developed an exciting new solution to this problem: ANYmal. It is a highly sophisticated four-legged robot, designed to tackle the challenges of a harsh industrial environment head-on. Resembling a medium-sized dog and weighing in at 30 kg, it teams high-end computer systems with robust hardware and is equipped with sensory systems to perform search and rescue operations, inspections, and other surveillance duties.

Meeting the challenge of dynamic mobility

ANYmal was born from a need for a robot that can move easily over challenging terrain such as found at industrial sites. The ANYbotics team applied a specific focus to enhanced mobility, locomotion and robustness while ensuring the robot was safe to handle and easy to maintain by a single operator.

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A quadruped design offers the best advantage in terms of mobility and versatility, but their legs cannot be powered by a classical mechanically geared system, as employed by almost all robotic arms. This type of actuator (a component of a machine responsible for moving and controlling a mechanism or load) can only produce slow and static locomotion (i.e., always balanced) to reduce impulsive forces, which occur when two bodies collide, such as when a leg contacts the floor.

The robotic research community put forward several solutions to get around this problem. One promising approach are Series Elastic Actuators (SEAs). The design of these compliant actuators is inspired by nature; tendons and muscles working together to control force. SEAs can be described as actuators attached to the load via a spring or elastic element. This clever set up allows a force to be controlled precisely; as the spring expands or contracts it supplies information about the force applied.

In addition, the spring absorbs impact, having the effect of increasing shock tolerance. It can also store energy temporarily during locomotion, increasing energy efficiency and peak power.

ANYdrive – A powerful, torque-controlable robot joint

The ANYbotics team has developed with ANYdrive their own SEA unit, a compact, tightly integrated and sealed actuator module containing custom control electronics. ANYdrive can regulate the joint torque, position and impedance directly, without the need for any additional components. Using ANYdrive as a base, a robot will be simple to manufacture, assemble and maintain. In case of failure, an ANYdrive joint can be exchanged quickly and easily.

The ANYdrive units make ANYmal unique. Each leg has three of these joint units, allowing a wide range of movement: hip abduction/adduction, hip flexion and knee flexion/extension. They allow ANYmal to walk, trot and jump, as well as walk and crawl up stairs. These joints can be fully rotated, allowing the legs to turn overhead to prevent collision with the ground or side rails, as well as get up after a fall.

ANYbotics emerges from research

ANYmal's ground-breaking technology began in the legged robotics group at the Autonomous Systems Lab, ETH Zurich and further in their Robotic Systems Lab. Nine years of extensive research went into the development of ANYmal and its component products. The ARGOS (Autonomous Robots for Gas and Oil) challenge, organised by the French Oil & Gas group Total, provided the first platform to demonstrate ANYmal's capability of navigating and moving dynamically in very challenging terrain. Numerous advanced autonomous surveillance and intervention tasks were completed safely on a replica of a multi-floor industrial oil and gas platform in a potentially hazardous offshore environment.

From this successful outing came the creation of a commercial spin-off company, ANYbotics, allowing for the commercialisation of both ANYmal and the ANYdrive component that makes ANYmal so unique.

A collaborative research community

Together with its partners, ANYbotics has founded the collaborative research community 'ANYmal Research' to develop and share software and other information to improve and extend the capabilities of the ANYmal robot. Members include the Toyota Research Institute, the German Aerospace Center (DLR), Nvidia (computer hardware and software) and several prestigious universities. This research community has full access to ANYmal's control software, simulation, documentation, and community support.

protection housing, foam absorbs the impact of side falls and a Kevlar belly protects from sharp objects below. The main body holds the computers, batteries, network devices, power management system and navigational sensors. It is sealed against water and dust ingress, complying to IP-67 standards. ANYmal can work autonomously for two to four hours before recharging and connects to a docking station independently.

The powerful brain of ANYmal, housed in the main body, consists of several computers for locomotion control, localisation and mapping, and for the specific task it is undertaking. All electronic components are thermally connected to an actively-cooled heat sink to prevent them from overheating. ANYmal's software is built on the open-source Robot Operating System (ROS), allowing for quick integration in an existing framework and the re-use of available software.

Real-world capabilities

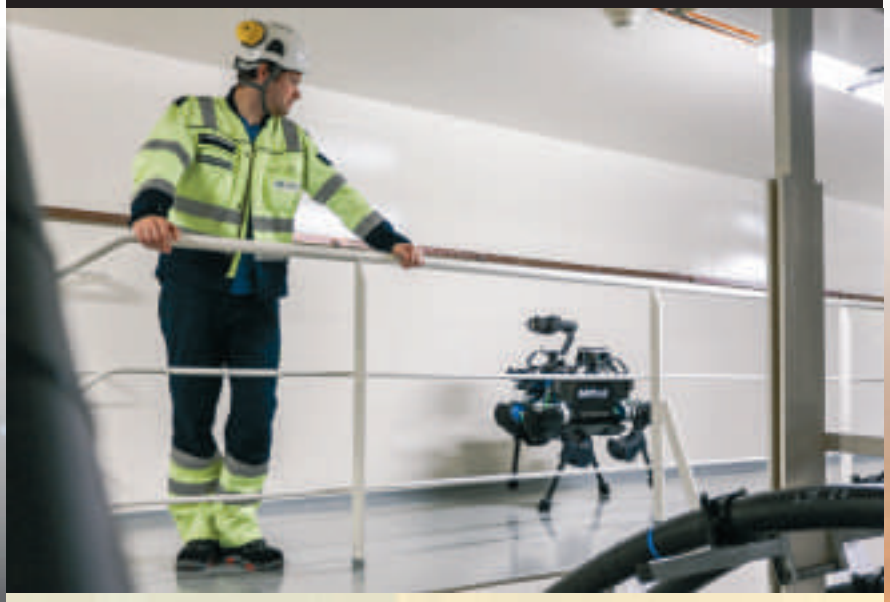
ANYmal has a proven capability of working in harsh environments with the potential for use in a wide-range of applications. It can operate in rough outdoor locations, crawl through pipes, and access buildings over steps and stairs, making it perfect for use on industrial platforms, in mines, construction sites, or patrolling remote locations. ANYmal's use in the industrial sector will not only increase efficiency and reduce operational costs, but it will also reduce the risk to personnel, installations and the environment. In addition to this, ANYmal can support disaster relief teams with safer search and rescue operations, as well as other activities that may involve human interaction.

ANYmal is not (yet) ATEX certified, however ANYbotics has carried out a number of successful pre-studies and this is definitely on the roadmap for the future. ■

About the author

Dr. Péter Fankhauser is chief business development officer of ANYbotics, which was founded by ETH Zurich (Switzerland) researchers and engineers in 2016. Having worked on legged robotics since 2009, the group spun off from the Robotic Systems Lab (RSL) to bring the ANYmal robot and the ANYdrive robot joint to real-world applications.

World's first **autonomous offshore robot**



In September 2018, the ANYbotics field team boarded a helicopter to fly out to one of the world's largest offshore converter platforms in the North Sea. Equipped with a customised sensorhead, the four-legged robotic platform ANYmal autonomously performed various inspection tasks of the platform in a one-week pilot installation, making it the world's first autonomous offshore robot.

Offshore wind farms

Offshore energy production is a key component of the global energy supply. Apart from oil and natural gas extraction, wind energy is increasingly being produced offshore. One of the key innovators in this field is the Dutch-German transmission system operator TenneT, which connects large-scale offshore wind farms to the onshore grid over a high voltage DC connection. Set out to provide reliable and low-cost energy transmission and distribution, the company has a history of adopting many recent technologies.

Robotic inspection with ANYmal

ANYbotics is partnering with TenneT to evaluate robotic inspection and maintenance on their offshore converter platforms. In periods of unmanned platform operation, a mobile robot helps to reduce the risk of disruptions and ensures the security of the electricity supply. Based on its autonomous navigation capabilities, ANYmal performs routine inspection tasks to monitor machine operations, read out sensory equipment and detect thermal hotspots and oil or water leakages. Whenever required, ANYmal can be remotely operated from an onshore control center in order for TenneT to receive real-time information through the robot's onboard visual and thermal cameras, microphones and gas detection sensors.

Successful pilot installation

After being taken on a guided tour of the platform to 3D-map the environment and learn the position and characteristics of all inspection points, ANYmal autonomously navigated the platform and processed inspection protocols. The video below documents a fully autonomous mission, covering a total of 16 inspection points such as gauges, levers, oil- and water levels and various other visual and thermal measurements.

www.anybotics.com/2018/10/25/worlds-first-autonomous-offshore-robot

ANYmal features and capabilities

The modular design of the hardware and software of ANYmal simplifies setup and maintenance. Physically, it is constructed of a single carbon-fibre lightweight body, with 12 identical joint units connected by simple mechanical links. Environmental perception is enabled through lidar sensors, stereo and wide-angle cameras; sensors in the rubber feet provide haptic information. The payload can range from simple sensors to complex robotic arms for manipulation, depending on the application. For industrial inspection, ANYmal is equipped with a pan-tilt head with various sensors, including an optical zoom and thermal camera, a gas detection sensor, an ultrasound microphone for gas leak detection, as well as artificial LED lighting.

ANYmal can survive falls from over 0.5m height; sensors are equipped with a fall-