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Abstract:

The Robotics Innovation Center (RIC), headed by Prof. Dr. Frank Kirchner, develops mobile robot systems that are able to solve complex tasks on land, under water, in the air, or in space. These design concepts often benefit from the variety of nature: climbing/walking four-, six-, or eight-legged robots, snake-like underwater vehicles, and dual-arm transport robots resemble patterns from a natural environment, combining advantages of new materials with successfully evolved locomotion patterns and forms.

Detailed research information:

ASGUARD

For outdoor locomotion of mobile robots, one has to cope with different requirements for such systems. These robots have to be highly agile and fast on flat ground and, at the same time, should be able to deal with very rough terrain, e.g. rubble, gravel, and even stairs. This is particularly true for robots, which are used for surveillance and search and rescue missions (SAR) in outdoor environment as well as for robots for remote inspection, such as CBRNE detection in crises situations. Tracked robots are currently regarded as the best trade-off between high velocity and mobility in rough terrain. Those systems have the drawback of high-energy consumption due to friction and are generally not able to climb stairs or very steep slopes.

Figure 1: ASGUARD

The two other locomotion modes are legged robots (as for instance Scorpion), which are very agile but lack speed and the classical wheeled systems. To get the best of both those modes, we developed the hybrid legged-wheeled robot ASGUARD (cf. Figure 1). The robot was designed to be used in harsh outdoor environment with a focus on security and outdoor surveillance as well as on disaster mitigation missions. For those applications, a robot has to transport a variety of mission-depending application sensors inside a difficult terrain. ASGUARD can climb stairs by using an adaptive, bio-inspired control approach. With the same controller configuration, the robot can traverse flat and even ground with high speed. In further iterations, ASGUARD has been provided with custom-made high-performance motor controllers that would help improving its capabilities even more.

SCORPION

The SCORPION is an eight-legged walking robot for hazardous outdoor-terrain. It can go to where other robots get into trouble. It uses a bio mimetic control concept, which allows a very flexible, robust walking behaviour. The walking gaits of the SCORPION robot are based on research on walking patterns of real scorpions.

The SCORPION can be controlled in an intuitive way with a GUI and an optional voice control. The developed models of the biological motor systems enable the robot to adapt autonomously to a multitude of different terrains and obstacles.

Figure 2: SCORPION

Possible future fields of application include exploration of hazardous environments, e.g. in SAR missions. Currently an amphibious version of the SCORPION is under development. A copy of the SCORPION is in use at the NASA Ames Research Centre to evaluate the advantages of legged systems for extraterrestrial missions.

CESAR

The CESAR robot was designed and built at the University of Bremen in order to participate in the ESA Lunar Robotics Challenge. The CESAR team is headed by Prof. Dr. Frank Kirchner.

Figure 3: CESAR

The CESAR Robot uses a hybrid legged wheel design with 5 feet per wheel to negotiate difficult terrain and climb over obstacles. The wheel shape enhances off-road mobility and helps to keep the centre of mass low on obstacles. An articulated camera head and headlights enable the operator to control the robot inside the crater and to monitor the sample collection. The shovel that is used to collect and store the soil sample is located in the in the rear section of the robot.

The CESAR platform weights 8kg and is powered by lightweight lithium-ion batteries. The robot weight was minimized using lightweight plastics and carbon fibre material as structural parts.

One of the difficult tasks was to build a robot that could climb a 40-degree steep crater incline covered with loose gravel. Adding an active paddle in the back helped to improve the climbing performance.

Different foot designs were developed and tested on the CESAR platform. The feet have to be rugged, provide enough traction on steep inclines and prevent the robot from digging into the loose ground. The fibreglass foot provides enough surface area to support the robot and uses two claw-like toes to create a foothold on the loose substrate.

In the night of the competition, the CESAR team was able to manoeuvre the robot into the completely dark crater and find the visually marked soil sample. 100 grams of soil were collected and stored in the sample collection unit. The robot also managed to climb out of the up to 40-degree steep crater and deposit the soil sample in the desired location. With this performance, the CESAR team won the first place in the ESA Lunar Robotics Challenge.

ARAMIES

The ARAMIES robot comprises 26 active joints, 6 in each leg and 2 for actuating the head, which includes a camera, a laser scanner and two ultrasound distance sensors.

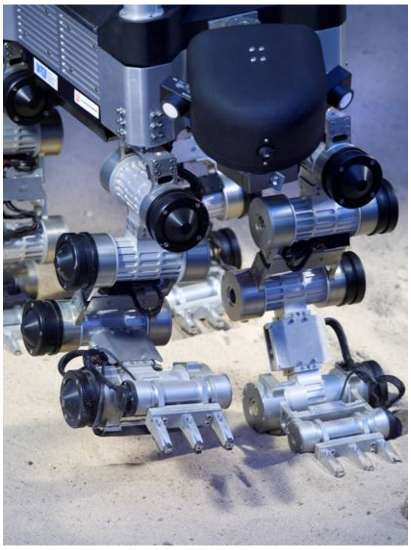

Figure 4:ARAMIES

In addition, the system has acceleration sensors and gyroscopes for stability control. Furthermore, each joint is equipped with absolute position sensors, current sensors, and temperature sensors.

One major advantage of the ARAMIES robot in comparison to other walking robots is its actuated claw, which is used to get a hold in steep inclinations. In laboratory tests, the system was able to climb up a rung wall with an inclination of 70°.

Each claw is equipped with five pressure sensors and an additional special IR-distance sensor, which are used for robust ground contact detection.

The modular control and power hardware consists of a PC 104 system for high-level control (e.g. navigation & planning), a MPC 565/FPGA board for the reactive behaviour-based control, and 5 FPGA controlled motor boards. Each of these motor boards can control and drive up to 6 motors and read in all analogue sensors signals from the joints and the claw. Up to 8 motor boards can be connected to the MPC565/FPGA-board using LVDS-communication.

Mehen

The snake-like robot Mehen is an experimental platform for testing various undulating movement techniques in water. An undulating movement is especially useful where the robot should move in a minimal invasive way, e.g. during monitoring missions in reed areas or at banks of lakes and rivers.

Figure 5: Mehen