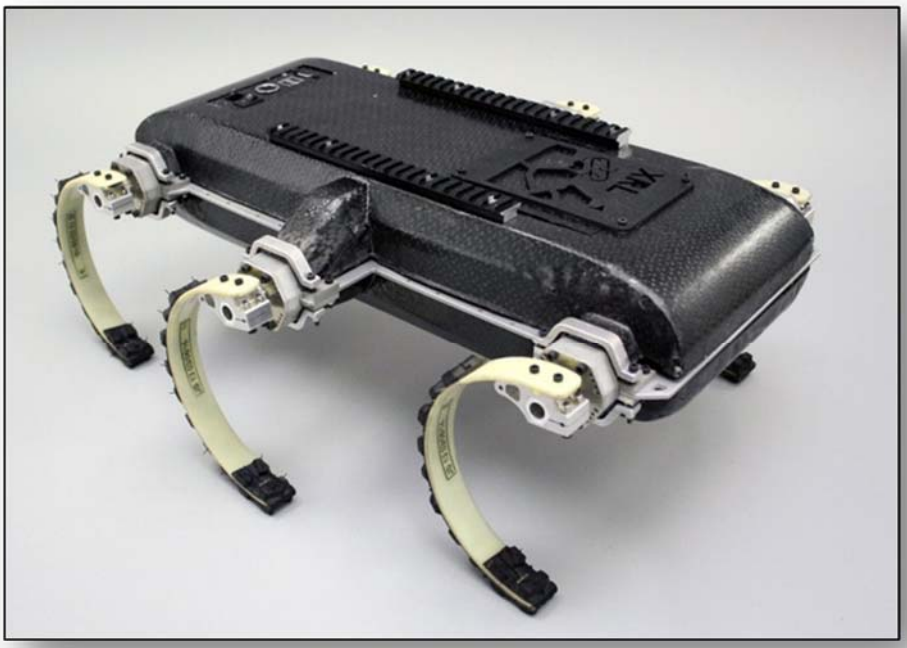
Hexapedal Robot

Whether traversing over the sands of Mars, or walking up a stone path, this robot was designed to move easily and quickly, to jump, and even to flip over.

The biologically inspired robots being designed at the University of Pennsylvania aim to provide new levels of mobility and durability, while providing the capability for rapid behavior development. The X-RHex (Robot Hexapod) is the latest version of the highly mobile RHex platform. X-RHex was designed for greater strength, longer runtime, and more mobility than previous versions, plus it is the first RHex to be built to carry a modular payload architecture to support a wide variety of research requirements.

The six legged robot is modeled after insects where three legs are always touching the ground at the same time. As a running robot, the X-RHex provides robust operation in complex, natural, outdoor terrain. The robot is expected to be an effective research machine for in the laboratory as well as outdoors for field tests.



*The X-RHex robot can travel over any surface using its C-legs. This model features rail-mounted handles. © 2013 Kod*Lab*

The payload specifications include a 5V, 12V, and battery voltage (37V to 42V) power interface, and a USB and Ethernet connection. Payloads are attached to the robot using mil-spec Picatinny rail mounted standard interface. While typical payloads are often smaller in mass than the X-RHex itself, the robot has been tested for carrying up to 12kg on its back, which is significantly heavier than the weight of the robot. Payloads can include webcams, GPS units, and a secondary computer for fast processing of sensor data.

The X-RHex body is 57 x 39 x 7.5 cm, with a ground clearance of 12.5 cm (12 cm when inverted). Each leg has a diameter of 17.5 cm, and the unit weights 9.5 kg with both batteries installed. One of the main objectives for the mechanical design of X-RHex was to improve its frame durability in both resistance to fatigue and impact, as well as serviceability while achieving better performance than past models of RHex.

Leg design, on the other hand, was preserved. The leg mounts are nearly centered on the thinner body, which means the robot operates with greater ground clearance even when in an inverted state. The motors were chosen after careful analysis of the performance of past RHex robots. The team chose to use flat brushless motors designed and manufactured by maxon motor USA. Each motor offers 84 Watts of continuous power, has a gear ratio of 28:1, and a maximum robot power density of 240 W/kg.

The X-RHex is designed around four subsystems, including a main computer, electronics stacks, batteries, and motor assemblies. While the main computer handles all high-level control and communications; the electronics stacks house the motor controller, control interface board, and the battery management board used for power distribution, regulation, protection, and monitoring. Mounted to the outer side of each stack is a lithium polymer batter and interface board. A motor assembly, which contains the brushless motor and related sensors, is located at each of the six hips.

*The XRL is a lighter version of the X-RHex that is designed specifically to be more agile while maintaining the same leg spacing as the original RHex. It also features the same modular payload architecture to support a variety of research needs. © 2013 Kod*Lab*

X-Rhex travels at a high speed of about four body lengths per second (about two meters per second). The motors used are maxon EC 45 brushless motors. There is one located at each of the six C-legs (the leg is shaped like a C). The C-legs are basically springs, which are compliant in both vertical and rotational direction. This means that the legs can push even though they rotate. Brushless motors are perfect for this type of application because they are high-efficiency motors, they have no friction due to the brushes, and produce no sparks while in operation.

maxon motor provides a wide array of motors, gearheads, controls, and accessories to the robotics industry. Their high-quality, long life products are especially suited for accurate operations like those needed for the X-RHex robot.

maxon designs and manufactures their complete line of both brush and brushless motors in-house. They also provide gearheads, encoders, and other accessories for their motors, including a wide array of electronics. The company's EC flat brushless motors are available in power ratings from 12 to over 70 watts, and come standard with Hall sensors. The motors are also available in a variety of operating voltages, as well as speeds and torques. maxon motors offer long life and quiet operation.

There are two phases to each leg's operation: the ground phase and the aerial phase. Like an insect, three legs are in each phase of operation at any particular time. This provides static stability for the robot. The gait is called an alternating tripod gait, and is the most stable operation for a six-legged machine.

The ground phase of the rotation has to move at a slower speed and requires a higher torque rating. The aerial phase of the rotation needs to move at a faster speed, but requires lower torque. This is because the legs are on the ground for only about 60 to 90 degrees of rotation, while they are in the air the other 270 to 300 degrees of rotation.

Further, friction is created while the C-leg is in its ground phase no matter what the terrain. Since the X-RHex can travel over rocks, sand, dirt, grass, the floor of a building, etc., the time the leg spends in the ground phase versus the aerial phase is variable. Note that not all gaits have to be tripod based, either. But, to be as flexible as possible, different algorithms must be created for each gait dependent upon where the robot is expected to travel.

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