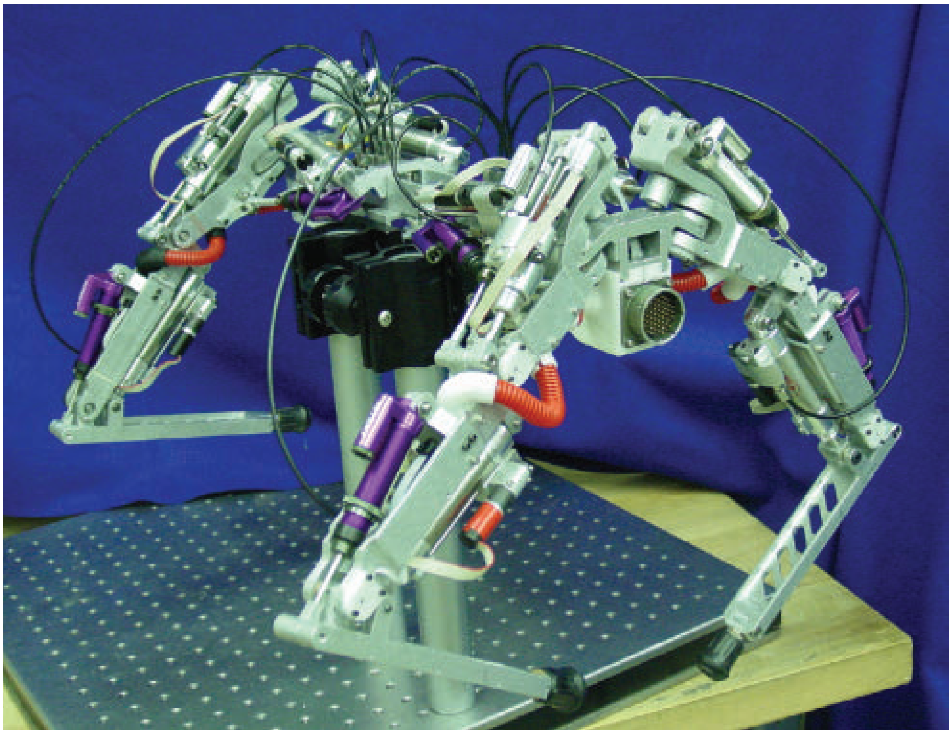


One of the more interesting projects being researched by the Center for Compact and Efficient Fluid Power (CCEFP) is a robotic walker, which ultimately could be used to develop a "rescue robot" that could assist in disaster situations. Here is a look at the fully integrated robot mounted to a lab table at Vanderbilt University, where it is undergoing bench testing.

HYDRAULICS TO THE RESCUE?

Legged robot program a test bed for smaller fluid power technology; research could one day lead to development of life-saving machines

BY MIKE BREZONICK

Advanced research in any discipline can often appear somewhat esoteric, akin to the mountain climber's "because it's there" proposition. And certainly it's fair to say that some of the research efforts fostered by the Center For Compact And Efficient Fluid Power (CCEFP) might appear to be some stretch from practical, real-world application.

Yet while CCEFP-sponsored research into the development of a "rescue robot" is at its core intended as a test bed for adapting fluid power systems to smaller applications, there were also some more noble motivations at work.

The project, which was initiated in 2006, is intended to develop and demonstrate a fluid-powered, compact, multi-legged robot with significantly improved force, power and energy capabilities relative to motor-/ battery-powered versions and to demonstrate intuitive, effective and efficient human control of the test bed. Research is being done in parallel at Vanderbilt University and at the Georgia Institute of Technology. The CCEFP is an Engineering Research Center for the National Science Foundation.

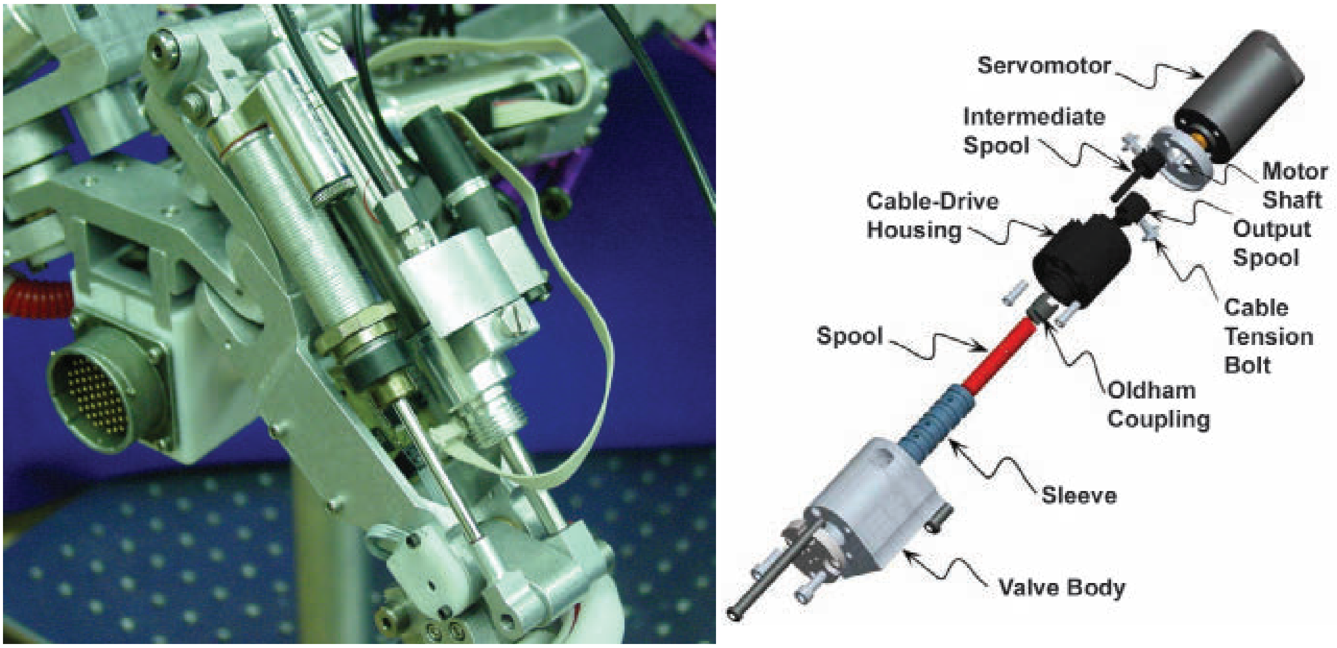
"Robots appeal to the public and to young people, our students," explained Prof. Wayne J. Book, Husco/Ramirez Distinguished Professor of Fluid Power and Motion Control at Georgia Tech, who along with Vanderbilt's Prof. Michael Goldfarb developed the "rescue robot" research proposal. "They can see a side of fluid power that goes beyond the conventional.

"At the same time, a legged robot has many of the control problems of conventional hydraulic machines, particularly in those situations that the expertise and judgment of a human would be needed. This could be expected in highly unstructured disaster situations."

Disaster situations were on the mind, Book noted, because "we were writing

continued on page 26

Some information for this article is from the technical paper "Design and Control of a Biomimetic Hexapedal Walker," by Keith W. Wait, Skyler A. Dalley and Michael Goldfarb.



A closeup view of the actuation system for an individual joint of the rescue robot, along with a schematic that describes the system components.

the proposal at a time when the inadequacy of rescue technology was on the minds of many, including myself. The World Trade Center, Katrina, earthquakes, mine collapses ... all seemed to need better technology."

The rescue robot research is expected to result in three test bed generations. The first generation, which is currently the focus, is a pneumatically controlled machine driven by hydrogen peroxide. The second generation will incorporate pump-driven hydraulics, and the final generation will be powered by a free-piston engine that is being developed as part of another CCEFP research effort. In all cases, the robots are intended to be untethered, though not completely autonomous.

The schools are each focusing on different aspects of the development, said Keith Wait, a graduate student at the Center for Intelligent Mechatronics at Vanderbilt and the president of the CCEFP's Student Leadership Council. "Georgia Tech's work is mostly concerned with developing novel human interfaces for fluid-powered machines," he said. "Specifically, they are interested in teleoperation of the walking robot and haptic interfaces for negotiating complex terrain through one-leg-at-a-time style motions.

"At Vanderbilt, we are more concerned with minimal human input-type gaits — think RC car style interfaces — for traversing level and clear terrain, as well as with design and low-level control problems for small-scale fluid-powered systems."

The development of "walking" machines has been the subject of a good deal of research over the years. This is in part because legged locomotion offers an array of advantages over other types of transport over uneven or irregular terrain. The CCEFP research initially focused on the concept of a hexapedal, or six-legged robot, because of its inherent stability in most gaits. As the development progressed, the effort has been aimed toward development of a quadruped, or four-legged machine, which would inherently require fewer components and improve the machine's uptime.

A liquid monopropellant-as-a-gas-generator (hydrogen peroxide) approach is being employed, as it provides greater power density relative to battery-powered/electric motor-actuated approaches. The use of monopropellants as a power source retains the benefits of pneumatic actuation, such as compliant interaction with environments, while dramatically improving power and/or energy density over phase change or compressed gas storage methods. These low-impedance dynamics have been demonstrated to allow a closer approximation to the dynamics of biological walkers.

The liquid propellant is pressurized by a CO_2 cartridge and is pushed through a catalyst pack by the opening of one or more servovalves downstream. As the liquid propellant passes over the catalyst contained in the catalyst pack, the liquid passes into a gaseous state and acts as the working fluid for the gas servovalves and pneumatic actuators.

The design of the robot's structure was inspired by Carausius morosus, commonly known as an Indian stick insect. This particular species of phasmid is frequently used in laboratory and school research. The mechanical design is intended to generally reflect the form and leg structure of the insect only so far as to achieve optimal walking performance. The robot approximates a 15:1 scale to the insect.

continued on page 28

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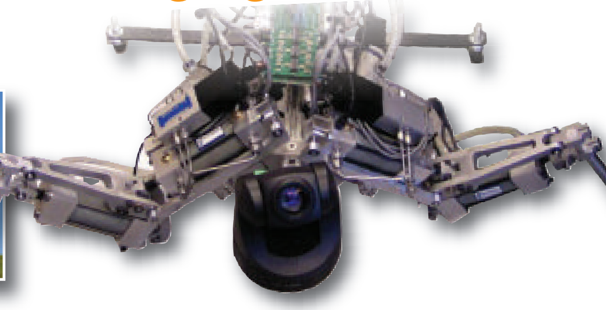

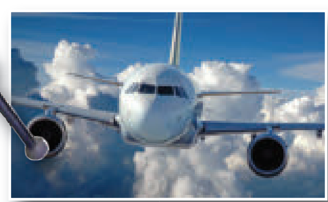

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Attached to the central spine of the robot are modular leg pairs. Each leg pair incorporates a left and right leg, their associated pneumatic actuators and common central brackets. Additional brackets located on the spine provide additional structure and alignment for the routing of fluid lines, mounting of an onboard fuel tank and additional valves, actuators and electrical hardware.

In the animal, the leg pairs depart from the central body axis in the horizontal plane at unique angles, while all angles of departure in the robot are 90°. The legs consist of three segments and three joints. Each of these joints is actuated by Bimba pneumatic cylinders mounted to the preceding segment or the central spine.

At each leg joint, integrated Alps potentiometers measure the joint angle and are protected and secured to the robot by plastic covers. Wiring is routed through channels in the leg segments and spine. During the initial development, the position signals are transmitted to the control computer via a 9.8 ft. umbilical. The umbilical will be eliminated later.

Liquid hydrogen peroxide from the fuel tank is fed downstream via flexible tubing to catalyst packs filled with iridium-coated alumina granules. These catalyst packs then feed hot gas (steam and oxygen) directly into manifolds and their associated servovalves that are mounted on or adjacent to their corresponding gas actuators.

The servovalves are powered and controlled by custom onboard microcontroller-based electronics designed as part of the project. The circuits sample valve position at 1 kHz and are capable of delivering 1.2 Amps at 12 V to the Freescale H-Bridge motor drivers that operate the valves.

Valve angle position is read by the servocontroller in its valve control loop. Leg joint angle positions are transmitted as analog signals from the potentiometers to the offboard PC. Position control of each individual leg uses a standard position-velocity-acceleration (PVA) approach.

"Standard pneumatic components are used," Wait said. "All the fittings are Beswick Engineering miniature compression fittings. Festo graciously donated many servovalves, which we used to develop our control methods as well as during early prototypes of the robots at both Georgia Tech and Vanderbilt. They worked well, but aren't compatible with the hot gas energy supply and are on the large side for mobile robotics, so we use custom valves.

"Bimba donated all of the pneumatic cylinders that were required for the original six-legged robot design as well as the current four-legged robot. Enfield Technologies provided some technical advice regarding the servocontrollers."

Much of the support for CCEFP research comes from National Fluid Power Association (NFPA) member companies. According to NFPA, more than 60 fluid power manufacturers, distributors and suppliers provide financial support to the CCEFP, and many also contribute equipment and provide volunteers who actively work with universities on project and test bed research.

Research is being done in parallel at Vanderbilt University and at the Georgia Institute of Technology. Georgia Tech's work is focusing on human-machine interfaces and shown here is a student operating the user interface test bed.

The final biological paradigm in use by the robot's control architecture lies in the coordination of the robot's legs. Decentralized coordinating mechanisms allow for a more stable gait and incorporate the effects of the environment on the robot into the robot's motion.

Book noted that Vanderbilt was expecting to have the robot powered without tether before summer. As of mid-February, Wait said, "there is a robot running around" in the lab. The unit is around 25 lb., and it is approximately 19 in. long and stands 12 to 14 in. off the ground. Wait said the external gas and hydrogen peroxide system will provide air at 300 psi. "With our actuator sizes and this pressure, we should be able to achieve something like 100 to 150-plus pounds of force at each foot."

While that will certainly be enough to propel the robot, ultimately the later generations will be engineered to be much more capable. "We want to truly assist in rescue, not only search as do current 'rescue' robots," said Book. "That means lifting debris that might pin a survivor, and 500 lb. is our current target.

"It might mean sawing open doors or pushing away debris. Some of this capability will come directly from the robot's actuators while in other cases jacks and saw's powered from the robot and positioned by its limbs seems more practical.

"As far as applications that make commercial sense, I believe they exist in forestry, agriculture, defense, construction. To predict them exactly shouldn't be necessary for fundamental research. Who would have predicted Youtube would result from DARPA research on networks that resulted in the Internet?" dp