Extended Abstract for the 2006 International Joint Topical Meeting: "Sharing Solutions for Emergencies and Hazardous Environments," February 12-15, 2006, Salt Lake City, Utah, USA

The Joysnake – A Haptic Operator Console for High-Degree-of-Freedom Robots

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The University of Michigan's Mobile Robotics Lab has developed a series of so-called "serpentine robots." These robots are slender multi-segmented vehicles that offer unprecedented mobility on rugged terrain, such as the rubble of a collapsed building. Our most advanced serpentine robot is the OmniTread-4 (OT-4) which has seven segments and 13 actuated degrees-of-freedom (DOF).

A problem with high-degree-of-freedom (HDOF) serpentine robots is that they often require more than one human operator. In the case of the OT-4, *three* operators simultaneously control the robot using six individual joysticks as well as auxiliary instrumentation (see Figure 1.)

Figure 1: Three highly trained operators are currently needed in order to control the OT-4 with its 13 DOF.

In order to reduce the number of operators needed, we invented a Haptic Operator Console (HOC), which we call the "*Joysnake*" (as in joy*stick*.) The premise of this invention is that the fastest and most intuitive method for a human operator to command a pose for a HDOF robotic mechanism is to shape an adjustable replica of the mechanism into the desired pose.

Figure 2: Side view of a mock-up of the Joysnake

We illustrate this patent-pending invention in Figure 2, which shows a non-functional mock-up of the Joysnake. The HOC is comprised of three parts:

1. The Joysnake (proper): This is the portion that the operator grasps and manipulates to control the shape of the serpentine robot. The Joysnake is instrumented with the electronics most necessary for its function and control of the OT-4.
2. The control tray: This is a small tray worn by the operator in front of their body, supported by a strap around their neck. Model airplane enthusiasts often carry their R/C joystick transmitters in a similar way. The tray contains all off-board electronics and the mounting linkage that the Joysnake is attached to.
3. Software: This is the driver software necessary to integrate the Joysnake's data with the OT-4's existing control system.

Emulating the design of the OT-4 at only a third of the size, the Joysnake has seven segments and six 2-DOF joints. The high friction joints are manually adjustable but hold their position when left alone.

The center segment of the Joysnake is linked to the control tray by a vertical pole with a 2-DOF head that allows pitch and yaw motion. This fixture holds the center segment suspended over the tray, thereby permitting the operator to position the Joysnake in almost any desired pose, without having to support it further.

From the perspective of the operator, the same side of the OT-4 always faces up, since the Joysnake does not permit roll. When the OT-4 rolls over, control software automatically remaps the "up side" of the Joysnake to the new "up side" of the OT-4.

In application, the operator controls the OT-4 much as a puppeteer might by holding the forward segments of the Joysnake in one hand and the hind segments in the other. On the top side of the lead segment there is a linear potentiometer that controls the forward/backward speed of the OT-4. The remaining six segments have sliders that control the stiffness of the OT-4's six individual pneumatic joints (see Figure 3.)

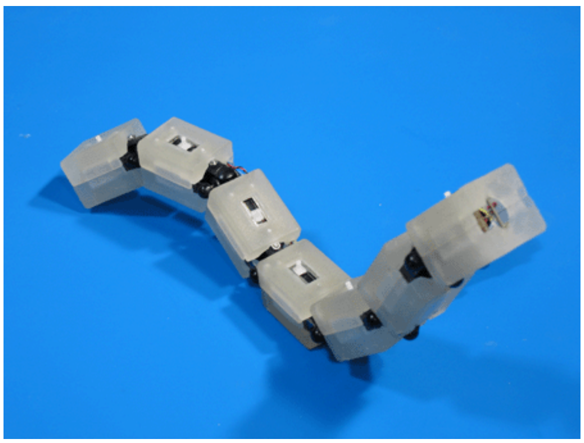

Figure 3: The *Joysnake* Haptic Operator Console, currently under development at the Mobile Robotics Lab. The Joysnake is the same size as the mock-up shown in Figure 2.

In order to measure the pitch and yaw angles of each Joysnake joint, mechanical linkages convert the angular position of the joint to linear displacements. These displacements are converted to electrical control signals by means of linear potentiometers located in the seven hollow segments of the Joysnake. The control software reads these signals and uses them as reference positions for the OT-4.

In addition, less time-critical functions of the OT-4 can be controlled via instrumentation built into the base tray of the Joysnake. For example, one switch activates an override slider, which commands the stiffness of all OT-4 joints in unison. This command overrides the individual stiffness settings determined by the linear potentiometers on the top of each Joysnake segment.

An advantage of the 'hands-off' nature of the Joysnake is that the operator may let go of it with both hands and perform auxiliary functions. The high-friction joints of the Joysnake maintain their orientation and the HOC continues to command the desired shape to the OT-4.

Current status

At the time of submitting this *Late-breaking News* item (11/10/2005), we have completely fabricated and instrumented the Joysnake (see Figure 3.) The control tray will be completed by the end of November 2005, as will the driver required to integrate it with our current OT-4 control software. This leaves two months for testing and refining before the fully functional Joysnake will be demonstrated at the Judged Showcase of this conference.

Future developments

If initial testing of the Joysnake as described above is successful, significant enhancements are possible. For example, by actuating the 2-DOF joints of the Joysnake and implementing force-feedback in the OT-4, a true haptic feedback user interface is possible (*haptic* is defined as the display of information through a person's sense of touch.) A haptic feedback user interface such as this conveys to the user where the OT-4 meets resistance in the terrain. In addition, the commanded stiffness of each joint is fed back to the user by changing the stiffness of the Joysnake.

Although the Joysnake was designed specifically for the OT-4, it would not be difficult to adapt its design for other HDOF serpentine robots. High-level artificial intelligence control schemes are being developed for such robots but may be years away from successful implementation. Until then, and likely in addition to high-level control methods, the Joysnake offers significant practical value by providing an intuitive haptic interface and reducing the number of operators needed.

Acknowledgements

This work was funded by the U.S. Dept. of Energy under Award No. DE FG52 2004 NA25587.

References

Borenstein, J., Hansen, M., and Nguyen, H., 2006, "The OmniTread OT-4 Serpentine Robot for Emergencies and Hazardous Environments." *2006 International Joint Topical Meeting: "Sharing Solutions for Emergencies and Hazardous Environments*, February 12-15, 2006, Salt Lake City, Utah, USA