MATLAB® Accelerates Spacecraft Docking Research at NASA Ames

The Smart Systems Research Laboratory, based at the NASA Ames Research Center in Moffett Field, California, is developing adaptive neurocontrol technologies—advanced computing techniques that can adapt to change—to improve operations in space. The group works with the NASA Johnson Space Center and collaborates with other NASA centers all over the country.

The goal of this particular project is to explore how neurocontrol technologies can optimize rendezvous and docking operations in space using computer-aided joystick control. Such a system could be used in docking the Space Shuttle and other space vehicles with the International Space Station (ISS).

Richard Papasin, computer scientist and engineering/technical lead of hardware and software development on Smart Systems projects, says that MATLAB® gives his group the flexibility to conduct research more quickly and cost-effectively.

The Challenge

Docking a vehicle in space is a time-consuming operation—docking the Space Shuttle to the ISS takes several hours—and it can be dangerous. Any sudden change in the conditions of either of the two docking spacecraft, such as the transfer of payload, can severely affect docking efforts. (An accident happened at the MIR Space Station in 1997 in a similar situation.) Other potentially dangerous situations include docking when a thruster is bent, stuck, or leaking; docking to a moving target; and attempting to rendezvous with and capture a disabled, spinning satellite.

Conventional joystick docking systems require accurate mathematical models of operational scenarios. The Smart Systems team needed to design a computer-aided joystick control system using standard joystick hardware. The system would need to automatically compensate for changes in spacecraft properties and enable safe, smooth docking under almost any conditions and without requiring pre-existing mathematical models. The system also had to be straightforward enough to enable anyone available to take control in emergency situations.

"Our goal is to make spacecraft docking and navigation safer and more efficient," Papasin says. "In some cases it needs to be fairly automatic so that non-pilot research personnel can maneuver a spacecraft through debris during an emergency and return to earth by simply pushing a few buttons."

The Solution

The Smart Systems Research Lab uses MATLAB to apply neurocontrol technologies that would detect and adapt to changes in spacecraft conditions.

The Challenge

To develop, study, and test adaptive neurocontrol technology for a computer-aided, joystick control system that will improve the safety and efficiency of spacecraft docking

The Solution

Use MATLAB® to develop system simulation, neural networks, and adaptive algorithms for the control system and use visualization products from Engineering Animation, Inc., to view the simulation

The Results

- Work completed in a fraction of the time
- Approval to develop an adaptive, neurocontrol docking system
- Additional research into related applications

The MATH WORKS

"MATLAB and WorldToolKit give us a development environment for creating learning algorithms and neural networks that is fast. We could have programmed in C or C++, but it would have taken five to ten times longer."

— Richard Papasin, M.S.E.E., Smart Systems Research Laboratory, Computational Sciences Division, NASA Ames Research Center

Essentially, they have merged adaptive neural network technology with nonlinear feedback control techniques to create an accurate model of the spacecraft based on its behavior. The system can correct, compensate for, or adapt to, many situations, including variations in thruster strength or angle, changes in payload size and position, and uncontrolled gas venting. It can also provide control for the rendezvous and docking to the ISS even when the Space Shuttle is translating or rotating.

The Smart Systems Research Lab uses MATLAB as the mathematical engine for its research and to develop and simulate physical models. "MATLAB gives us a rapid development platform," Papasin says. "It handles matrix operations very well. We can represent position, acceleration, and velocity in vector notation or a matrix. We rely heavily on the matrix operations in MATLAB."

To visualize their findings in an interactive, 3-D environment, NASA researchers combined their MATLAB models with synthetic environment animation using WorldToolKit® from Engineering Animation, Inc. Combining the capabilities of MATLAB and WorldToolKit allowed NASA to visualize the actual dynamics of the mathematical models.

The Smart Systems Research Lab's neural identification and adaptive control technologies will be used for a number of other applications. For example, NASA is using neurocontrol technologies to automatically balance the Stratospheric Observatory For Infrared Astronomy (SOFIA) airborne telescope while the telescope is in flight.

"What we are trying to do is make an adaptive neurocontrol system operate as much like a person as possible," Papasin says. "Just like a person, the system must be able to learn and react accordingly. MATLAB is helping us reach our goal."

The Results

- **Work completed in a fraction of the time.** According to Papasin, MATLAB saves the Smart Systems Research Lab time and money. "We could have programmed in C or C++," he says, "but it would have taken five to ten times longer."
- **Approval to develop an adaptive, neurocontrol docking system.** After showing their findings to NASA administrator Daniel Goldin, the Smart Systems Research Laboratory gained approval to continue their space-docking research. "This research is not just to improve today's Space Shuttle but also next-generation spacecraft, such as the escape vehicle for the ISS," says Papasin.
- **Additional research into related applications.** In addition to the spacecraft docking system, the Smart Systems Research Lab's neural identification and adaptive control technologies will be used for applications that include robotic neurosurgery, telescope balancing, adaptive optics, and aircraft control.

Application Areas

Aerospace

Adaptive control systems

Flight controls

MathWorks Products Used

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