University of Alabama

Critical infrastructure monitoring and control using real-time hybrid simulation

speedgoat
real-time simulation and testing

THE UNIVERSITY OF ALABAMA®

The University of Alabama researches critical infrastructure monitoring and control using real-time hybrid simulation to give vital information under disastrous loading conditions like earthquakes and strong winds.

The University of Alabama is a public research university located in Tuscaloosa, Alabama, United States. It was founded in 1831 and offers study programs in 13 academic divisions leading to bachelor's, master's, Education Specialist, and doctoral degrees.

Performance assessment

The university's Department of Civil, Construction and Environmental Engineering is conducting research into real-time performance assessment and control of civil infrastructure such as bridges and high-rise or public buildings.

Under disastrous loading conditions like earthquakes and strong winds, it is imperative to have real-time structural performance information available in order to optimally control damping devices to reduce the vibration, and to evaluate the damage so that an evacuation or repair plan can be formulated. There are several challenges: Hardware is required that can provide real-time computing power in the field, in a compact and rugged form. It must interface with multiple types of sensors, such as accelerometers, strain gauges and thermocouples. Dampers must be reliably controlled to reduce the motion of the structure.

Real-time hybrid simulation

The team uses real-time hybrid simulation (RTHS) as a cost-effective experimental technique for examining the behavior of complex, full-scale structural systems under realistic loading conditions. In RTHS, a structure is separated into a simulated component and a physical component. The simulated component is interfaced with the physical component in real-time within a closed loop through actuators and sensors. By testing a small portion of the structure (the physical component), the performance of the entire structure under dynamic loading conditions, such as earthquakes, can be determined. It can be considered as a Hardware-in-loop platform for large-scale structural testing.

Figure 1 shows how the principle is applied when studying the behavior of a building frame with a magnetorheological damper installed. The frame structure is simulated as finite element models and the real damper is tested in the laboratory.

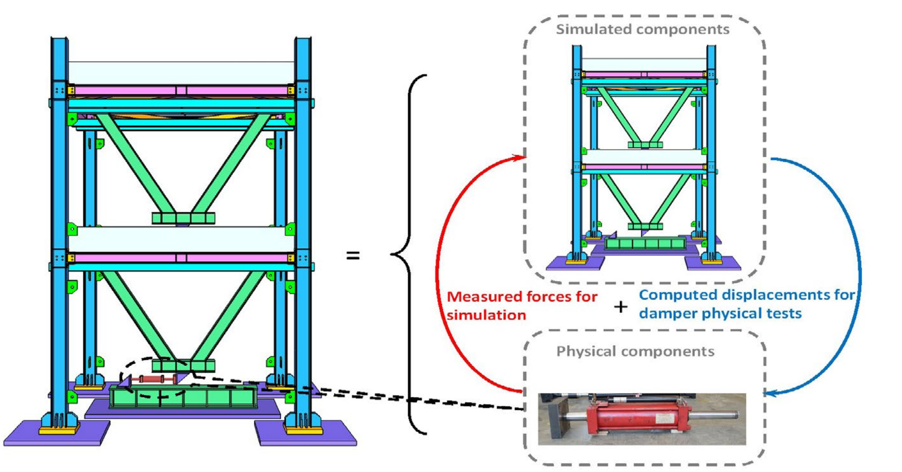

Figure 1. Left: Building frame with damper installed; Right: Simulated components (building frame) and physical components (magnetorheological damper)

Footbridge

For the research, a footbridge structure was first modeled and monitoring algorithms were designed. In the laboratory, tests were run with a Speedgoat real-time target machine connected to the thermocouples, strain gauges, and accelerometers. The monitoring algorithms were then integrated and tested. Finally the Speedgoat target machine and sensors were deployed in the field - see figure 2. The installed system was used to assess the condition of the bridge, and to update the model for the bridge in real-time.

To control the damper, the finite element models of the bridge structure were further developed for RTHS. Laboratory tests were then run using the models, with the Speedgoat target machine also controlling the damper to apply the desired displacement, and measuring force feedback from sensors on the physical components.

Results

Currently the project is still in the research phase. Once completed, the project funders may be interested in the production of the system.

As part of the project, the team has designed a delay compensation algorithm to effectively reduce the delay between the simulated and physical components in the tests. This will be reused in many other projects.

Speedgoat's value Contribution

"We needed a system that could interface with many different types of signals, including accelerometer channels, strain gauges, analog voltages and images. It is difficult or almost impossible to find one shop for it all, but Speedgoat helped us to accomplish this goal successfully.

Model-based design was used as it eases the design process with a controllable environment and can rapidly evaluate the performance of an entire system. The potential errors in the system can be easily identified and isolated" - Dr. Song

Wei Song, Ph.D.
Assistant Professor,
The University of Alabama

Figure 2. Sensors and DAQ installed on the bridge. From the top left picture, moving clockwise: strain transducer; accelerometer and its enclosure; Speedgoat real-time target machine and its enclosure; pedestrian traffic counter

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Speedgoat products used

- Automation real-time target machine
- IO710 EtherCAT Master I/O module
- EtherCAT Master and Slave protocols support
- Resistance and IEPE support
- USB UVC Webcam protocol support

MathWorks software used

- MATLAB®
- Simulink®
- MATLAB Coder™
- Simulink Coder™
- Simulink Real-Time™

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