A LabVIEW-Based Exercise Physiology Assessment System

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The Challenge: Integrating existing devices used to assess physiological responses to exercise into an automated system for data acquisition and analysis.

The Solution: Developing a PC-based system using SCXI and DAQ products controlled by LabVIEW.

Introduction

In our exercise physiology laboratory at the U.S. Army Edgewood Chemical Biological Center, we monitor and record several key parameters during stress testing. We use many different electronic instruments, designed to function as stand-alone devices, for complete assessment of human physiological response to exercise stress. One of our research projects is to assess the effects of wearing a protective respirator, or gas mask, during exercise. Our list of instruments includes heart rate monitoring equipment, flowmeters, pressure transducers, a medical gas analyzer, and other devices such as temperature probes and timers.

With so many different devices required, our challenge was to integrate them into a single, user-friendly automated instrument system.

The exercise assessment system consists of a 200 MHz Pentium PC running Windows, equipped with an AT-MIO-16E-2 DAQ board, which is connected to an SCXI-1122 16-channel isolated analog multiplexer module. Our LabVIEW program, named Treadmill.VI, acquires 400 samples/channel, at a rate of 20 samples/s, from six analog input channels.

System Block Diagram

Treadmill.VI, acquires 400 samples/channel, at a rate of 20 samples/s, from six analog input channels. The analog signals come from the following devices:

- High-speed medical gas analyzer (two signals – one for fractional oxygen concentration and the other, the fractional carbon dioxide concentration)
- Spirometric module (two signals – one for tidal volume and one for breathing frequency)
- Pressure transducer with a carrier demodulator
- Heart rate monitoring system.

Using two analog signals from the spirometric module, we calculate the primary exercise performance variables of minute ventilation, oxygen consumption, and carbon dioxide production. Likewise, because we already had a National Instruments E Series data acquisition (DAQ) board and various SCXI modules, we concluded that we could build a powerful, integrated virtual instrumentation system using LabVIEW.

The Exercise Physiology Application

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Because the start of data acquisition rarely coincides with the beginning of either an inspiratory or expiratory phase of a breathing cycle, acquisition of the ventilatory data is a challenge. Therefore, we built a comprehensive subVI to account for the acquisition of any partial breath data. In addition to the acquisition of ventilatory parameters, Treadmill.VI acquires fractional concentrations of expired oxygen and carbon dioxide within a mixing chamber from the gas analyzer. When testing calls for the
assessed physiological responses to protective mask wear, we also measure pressures within the mask face piece during the inspiratory and expiratory phases of breathing cycles, as we monitor the heart rate of the subject.

Using the LabVIEW graphical user interface tools, we created an easy-to-use operator interface for setting critical application parameters. We prompt the user to enter laboratory environmental conditions—temperature and barometric pressure. Treadmill.VI uses this data for correction of respiratory gas volumes (oxygen consumption, carbon dioxide production, and minute ventilation) to their proper reference temperatures and pressures (STPD and BTPS). In addition to simplifying the setup of the application, Treadmill.VI offers single-button operations for beginning and stopping the application. The duration of the application depends on either the specific test protocol in use or the exercise capability of an individual test volunteer. Upon termination of the application, Treadmill.VI automatically stores all measured data, as well as pertinent test configuration data—such as subject number, protocol log number, and mask wear condition—in standard ASCII format under the user-defined filename. We can then easily transport the data to the various database applications available in our laboratory.

The finished Treadmill.VI acquires data for 20 seconds, processes the data, and displays results on the computer monitor. The VI repeats data acquisition, processing, and presentation after a 10-second pause, thus updating its output every 30 seconds. By displaying the updated data both graphically and numerically, we keep the test administrator informed of the physiological status of the exercising subject. Likewise, the graphical interface helps medical personnel monitor the well-being of the subject under test.

Conclusion

In developing the Treadmill.VI application with LabVIEW, DAQ, and SCXI, we integrated into one PC-controlled system the various devices used in the laboratory to assess physiological responses to exercise.

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With the LabVIEW development environment, it was easy to build an application that monitors and stores critical performance data for the complete assessment of human exercise responses in our mask-wear research laboratory. Thanks to the flexibility of LabVIEW, we can easily modify this data acquisition system to meet the needs of virtually any exercise performance laboratory.

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