

Automated Industrial Wind Tunnel Network Control with LabView

Senior Project Proposal

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Project Summary

The purpose of this project is to upgrade the controls on the Mechanical Engineering Department's wind tunnel. The end goal is to create an easy to use user interface that will allow for both manual control of the wind tunnel and for executing predefined tests in the form of control sequences for the wind tunnel. In addition, the project will include the ability for remote operation of the wind tunnel for educational use such as in high schools. In order to make the system more robust, new National Instruments (NI) hardware will be installed. The new NI hardware will streamline the user input LabView control application with the new NI controller running LabView code.

Detailed Description

The Mechanical Engineering department would like to make measurements in their tunnel while using automated test sequences and to update their wind tunnel with a remote monitoring option for potential remote learning activity. In the past three years, three senior projects have made progress towards this end. The major missing component of these projects has been reliable components for the industrial environment. The block diagram in figure 1 shows the overview block diagram of the entire project that will be used to add this reliability. Bradley University students and professors will be able to control the wind tunnel through a LabView application with advanced direct control features and with automated test capabilities. Data from wind tunnel tests will be available in real time and through spreadsheets written with the test data. Drag force, lift force, pressure in the wind tunnel, pressure outside the wind tunnel, temperature in the wind tunnel, and temperature outside the wind tunnel will all be measured. A second application with simplified direct controls will allow high schools to run the wind tunnel from a remote location over an internet connection. Authentication will be required before either application is given control of the wind tunnel. Communication from the control applications will be sent over the Internet and through a network address translation router to the NI hardware. The NI hardware will have sole control over the operations of the wind tunnel when enabled. In case of extended connection loss with the control application the NI hardware will automatically safely shutdown the wind tunnel. In addition, if power is lost during a test the wind tunnel will shutdown and remain shutdown. Cameras will also be connected to the network so that wind tunnel tests can be observed remotely. Three linear actuators will be used to adjust the object in the wind tunnel during a test.

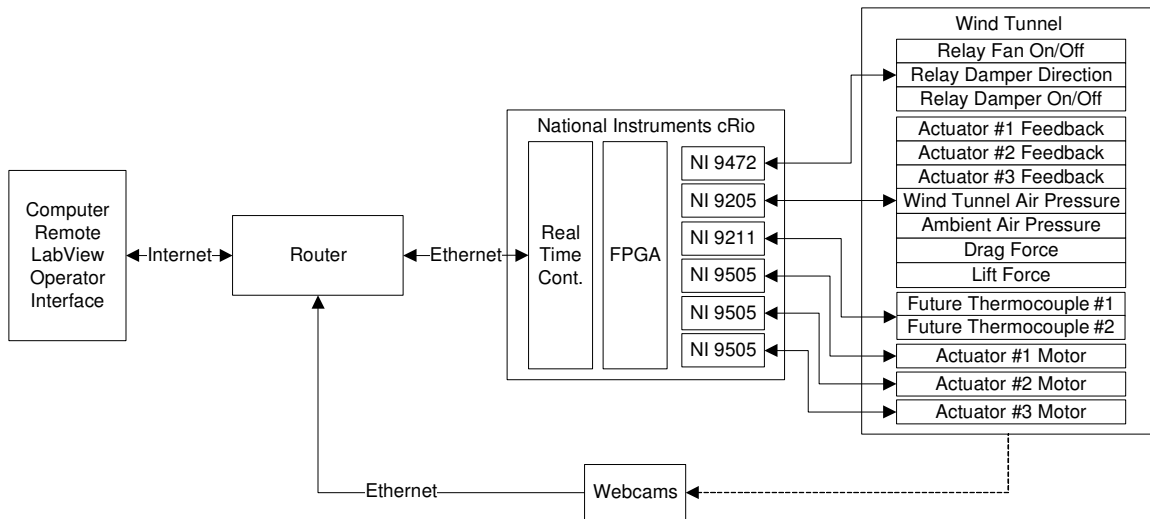


Fig. 1 - System Block Diagram

Computer Remote LabView Operator Interface

The remote LabView operator interface computer in figure 1 is the computer that will be running the LabView client application that connects to the controlling hardware over the internet. This computer will function as the user interface to control the wind tunnel.

Router

The router in figure 1 will act as the connection point from the internet to the cameras and the hardware that controls the wind tunnel.

Webcams

The webcam block in figure 1 consists of three webcams situated around the wind tunnel system. These will be placed to allow the operator to see how the part being tested is performing in the wind tunnel. They will also allow the operator to see the status of the surrounding area of the wind tunnel. The webcam handling will be modular such that more webcams can be added to the system.

Wind Tunnel

The wind tunnel block in figure 1 consists of a large blower turbine attached to a damper which then leads to the testing chamber. This damper can be opened or closed to adjust the speed of the air owing through the system. The wind tunnel also has a platform where the piece being tested sits. This platform has a linear actuator which can angle the test part up and down. Connected to this platform are two pressure sensors which are used to measure the lift and drag forces on the test part. There is also a fog machine attached to the wind tunnel which is used to visualize the flow of air over an airfoil.

National Instruments cRIO

The National Instruments cRIO in figures 1 and 2 is an expandable industrial controller. The cRIO includes an FPGA and real time controller. This combination allows for high

speed IO capability with the FPGA as well as real-time controller functionality that can both be programmed using LabView. The real time controller in the cRIO will be used to host the LabView web server as well as running control loops. The FPGA in the cRIO will be used as an interface between the real-time controller and the IO to allow for high speed IO control that may be desired in the future. The cRIO also offers many IO card options for interfacing directly to hardware without the need to add additional conditioning electronics. Figure 2 shows the cRIO with the cards installed that will be used for the project.



Fig. 2 - National Instruments cRIO

Analog Input NI - 9205

ADC Project Requirements

(Minimum 10-bit ADC Resolution)

- Wind tunnel pressure sensor (0-5V)
- Ambient pressure sensor (0-5V)
- Actuator one position feedback (0-5V)
- Actuator two position feedback (0-5V)
- Actuator three position feedback (0-5V)
- Lift force sensor (0-1V)
- Drag force sensor (0-1V)

National Instruments 9205 Quick Hardware Specifications

- 32 single-ended or 16 differential analog inputs
- 16-bit resolution; 250 kS/s aggregate sampling rate
- ± 200 mV, ± 1 , ± 5 , and ± 10 V programmable input ranges
- Overvoltage protection; isolation; NIST-traceable calibration

Thermocouple Input NI - 9211

Temperature Project Requirements

- Support for two future thermocouples

National Instruments 9211 Quick Hardware Specifications

- 4 thermocouple or ± 80 mV analog inputs
- 24-bit resolution; 50/60 Hz noise rejection
- Works over temperature ranges defined by NIST(J, K, T, E, N, B, R, S thermocouple types)

Digital Output NI - 9472

Digital Output Project Requirements (Transition time < 1s, 5-24V, 7mA)

- Solid state relay for fan on/off control
- Solid state relay for damper on/off control
- Solid state relay for damper direction control

National Instruments 9472 Quick Hardware Specifications

- 8-channel, 100 μ s digital output
- 6 to 30 V range, sourcing digital output
- Extreme industrial certifications/ratings

Motor Controller NI - 9505

Motor Controller Project Requirements

- Control FA-PO-150-12-4 linear actuator
- Bi-directional control
- Operating current 3 amps
- Inrush current 7 amps

National Instruments 9211 Hardware Specifications

- Continuous current of up to 5 amps at 40 °C
- Full H-bridge brushed servo motor drive with a built-in current sensor
- Peak current 12 amps < 2 seconds max
- Direct connectivity to actuators - fractional horsepower brushed DC servo motors, relays, lamps

Previous Work

Michael Firman and Benjamin Morisson Web Based Wind Tunnel Control System 2010

- System analysis
- Solid state relays to isolate control of damper and fan motors from control system
- Microcontroller and h-bridge design to control linear actuators

Adam Green Wind Tunnel Control (Remote Control and Measurement of Wind Tunnel System) 2011

- Network access to controls and measurements
- Use LabView on local PC to control wind tunnel
- Redesigned H-bridge interface with actuator(s) so that the attack angle of the object can be changed

Daniel Monahan and Nicholas DeTrempe Automated Industrial Wind Tunnel 2012

- Replace National Instruments analog to digital converter with microcontroller
- Work on LabView user interface

Matt Draear LabView Programming Experience

- LabView test equipment programming for Morton Automatic Electric 2012
- FIRST Robotics mentor - LabView programming 2011-2012

Preliminary Work

- Collected product requirements from customer
- Derived wind tunnel I/O control specifications from past project documentation

- Researched available LabView hardware for an affordable solution that would best interface as the wind tunnel controller
- Contacted National Instruments about the best way to host a LabView server
- Finalized functionality and hardware parts list by discussing it with the customer

Schedule

Task	Week Number	1	2	3	4	5	6	7	Break	8	9	10	11	12	13	14
	Week Starting	1/27	2/3	2/10	2/17	2/24	3/3	3/10	3/17	3/24	3/31	4/7	4/14	4/21	4/28	5/5
Create Basic Program to Test Hardware		█														
Test Individual Hardware Components			█													
Program FPGA I/O				█	█											
Program FPGA Control Loops					█	█										
Test FPGA Programming				█	█	█										
Program Real Time Controller FPGA Interface						█	█									
Program Real Time Controller Test Sequence							█	█		█						
Program Real Time Controller Web Server										█	█					
Test FPGA with Real Time Controller										█						
Program Client User Interface										█	█					
Test All Software Together											█	█				
Connect Hardware											█	█	█			
Test Complete System												█	█	█		
Write Final Project Paper														█	█	█
Preparation for Oral Presentation														█	█	█

Bibliography

[1] Ben Morrison and Mike Firman. “Web Enabled Wind Tunnel System”, Senior Project, Electrical and Computer Engineering Department, Bradley University, March 2010, <http://cegt201.bradley.edu/projects/proj2010/webwind/>

[2] Nick Detrempe and Daniel Monahan. “Automated Industrial Wind Tunnel Controller”, Senior Project, Electrical and Computer Engineering Department, Bradley University, April 2012, <http://cegt201.bradley.edu/projects/proj2012/aiwt/>

[3] NI CompactRIO, National Instruments, [Online] 2012, <http://www.ni.com/compactrio>

Equipment List

- NI cRIO - 9074
- Analog Input Card NI-9205
- Thermocouple Input Card NI-9211
- Digital Input Card NI-9472
- Three Motor Controller Cards NI-9505
- Local PC with LabVIEW software - (Real Time and FPGA Modules)
- Wind Tunnel System and Peripheral Components