

BRADLEY UNIVERSITY DEPARTMENT OF ELECTRICAL  
ENGINEERING

SENIOR CAPSTONE PROJECT:  
WEB CONTROLLED WIND TUNNEL SYSTEM  
DEVELOPMENT

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# Project Summary

Currently, the Bradley University Department of Mechanical Engineering has a small research wind tunnel. It is completely manually controlled and operated. Since all functions must be adjusted by hand and there is no digital control mechanisms in place, it is very difficult to get accurate, repeatable results. In addition, this also increases the amount of time required to take measurements with the wind tunnel, and increases the work load for the operator. The mechanical engineering department also would benefit from the ability to operate the wind tunnel system remotely. This would allow not only for easier data acquisition onto a personal computer or laptop for later analysis, but would allow other institutions which do not have access to a wind tunnel the educational experience of operating and collecting data from a real world wind tunnel.

To accomplish this task we will be updating the current wind tunnel platform with an embedded microcontroller capable of implementing a simple closed-loop controller which will allow for precise actuation of the wind tunnel components. This embedded microcontroller will also collect data from the various sensors and stream it to a host computer, which is running a webserver. Clients will connect through a Java interface and be able to view the current state of the wind tunnel and operate all functions as if they were in the room with the wind tunnel.

## System Block Diagram

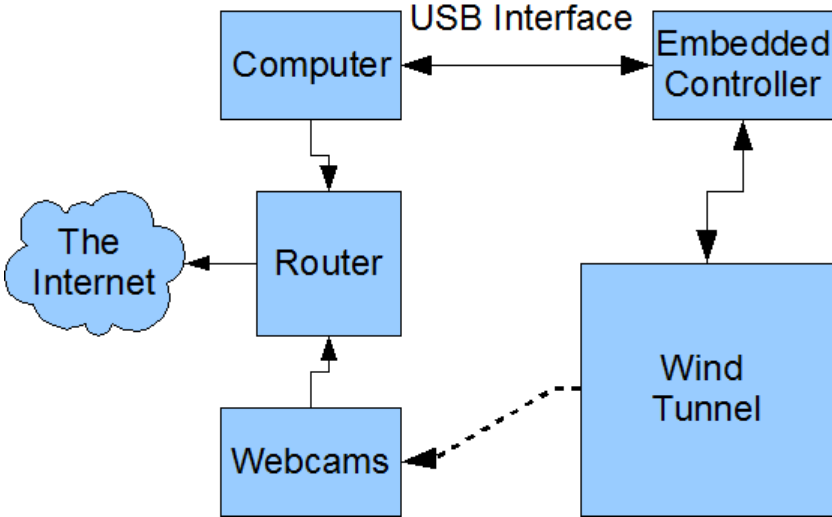


Figure 1 - System Block Diagram

# Functional Description

## Wind Tunnel

The wind tunnel block 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 flowing 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.

## Embedded Controller

The embedded controller block consists of an embedded platform which takes a series of inputs from the wind tunnel and can actuate the various controls on the wind tunnel and take measurements from the various sensors present. The controller will communicate through a USB interface to the host computer and interface to either Matlab or Labview. A webserver will collect this data and allow for remote access.

## Computer

The computer will communicate with the embedded controller platform and also host the web server which will serve the video streams and data to remote clients. The remote users will use a Java applet based UI to send commands through the host computer to the embedded system to operate the wind tunnel.

## Webcams

The webcam block consists of three webcams situated around the wind tunnel system. These will be placed to allow the user to see how the part being tested is performing in the wind tunnel as well as allow them 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 without any reconfiguration. They will merely need to be plugged into the router beside the current three webcams.

## Router

The router will enable the webcams and computer host to be internet connected. It will also handle the port forwarding necessary to allow the multiple camera streams to be embedded into the web-interface page.

## Goals

- Allow for remote starting and stopping of the wind tunnel
- Improve capabilities of the wind tunnel
- Creating an interface that is intuitive and easy to use
- Designing an embedded controller that could be mass produced for similar controls type applications

## System Requirements

- Controlling the wind speed within 2%
- Data rate of at least 10Hz
- Controlling the angle of the test bed to 5%
- Support for at least 10 simultaneous clients

## Relevant Patents

## Applicable Standards

## Results

This semester was mostly spent acquiring parts and doing preliminary testing of their functionality.

Two pieces of hardware were purchased, received, and tested so far during the lab time.

## **D-Link DCS-910 Ethernet Webcam**

This webcam is an ethernet enabled surveillance camera intended to be easily used in any kind of remote viewing application. It is simple to setup and comes with the ability to stream video through a java applet. Below is an image of the webcam purchased.



Figure 2 - DCS-910

The webcam is relatively small and comes with mounting hardware so it can be placed easily wherever it is needed around the wind tunnel.

## **Netgear FVS-318 VPN/Firewall Router**

The router that was purchased is a full featured, enterprise class router. It is capable of a wide variety of quality-of-service configurations and gives great flexibility over the network address translation setup. These are both important features necessary for the success of the project. Pictured below is the router that was purchased.

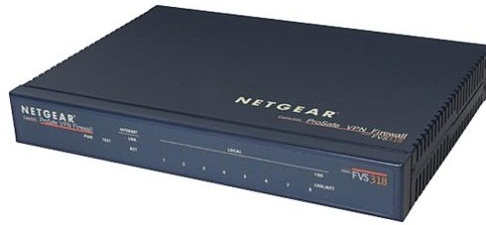


Figure 3 - FVS-318

This router has 8 ports on the back and has a metal casing. The overall build quality of the router seems very high and it looks like it will be more than adequate for our purposes.

## Discussion

Initial testing showed that both the router and webcam immediately showed up on the network and acquired an IP address properly. It did take some time learning the router software however to understand the functionality of the port forwarding. It does not operate in the traditional fashion found on many consumer level firewall/routers.

Once the port forwarding was established for the webcam it became visible on the network and the video stream from it could be accessed remotely. This verified the functionality of both the router and the webcam adequately. More testing needs to be done on the capabilities to stream multiple video feeds at once however we do not currently have the hardware to make that possible. We wanted to make sure that the camera would be adequate for our needs and so only purchased one of the required 3 cameras initially.



# Schedule

ID	Task Name	Start	Finish	Dec 2009		Jan 2010					Feb 2010			Mar 2010		
				12/20	12/27	1/3	1/10	1/17	1/24	1/31	2/7	2/14	2/21	2/28	3/7	
1	Choose Microcontroller	12/18/2009	1/20/2010	[Gantt bar from 12/18/2009 to 1/20/2010]												
2	Purchase Linear Actuator	12/18/2009	1/20/2010	[Gantt bar from 12/18/2009 to 1/20/2010]												
3	Purchase Additional Webcams	12/18/2009	1/20/2010	[Gantt bar from 12/18/2009 to 1/20/2010]												
4	Purchase Limit Switches	12/18/2009	1/20/2010	[Gantt bar from 12/18/2009 to 1/20/2010]												
5	Setup Apache Webserver	12/18/2009	1/20/2010	[Gantt bar from 12/18/2009 to 1/20/2010]												
6	Develop Webpage and UI	12/18/2009	1/20/2010	[Gantt bar from 12/18/2009 to 1/20/2010]												
7	Test Linear Actuator	1/26/2010	2/2/2010	[Gantt bar from 1/26/2010 to 2/2/2010]												
8	Design Interfacing Circuitry	2/2/2010	2/23/2010	[Gantt bar from 2/2/2010 to 2/23/2010]												
9	Develop Controller Code	1/26/2010	2/23/2010	[Gantt bar from 1/26/2010 to 2/23/2010]												
10	Design PI Controllers	2/23/2010	3/9/2010	[Gantt bar from 2/23/2010 to 3/9/2010]												
11	Develop Data/Control Server Application	2/23/2010	3/9/2010	[Gantt bar from 2/23/2010 to 3/9/2010]												
12	Overall System Testing and Integration	3/9/2010	3/16/2010	[Gantt bar from 3/9/2010 to 3/16/2010]												

Figure 4 - Project Gantt Chart

## Project Tasks

### Choosing a Microcontroller

We chose to use the SI Labs F120 board for the web enabled wind tunnel. This board has sufficient hardware to support the project.

### Purchase a Linear Actuator

Further research into an appropriate second linear actuator for the system will be necessary. Emphasis will be placed on finding an actuator which has a detailed data sheet.

### Purchase Additional Webcams

Some initial testing has been done on the current webcam confirming that it is capable of performing the tasks we need. Additional webcams may now be purchased.

## **Purchase Limit Switches**

Limit switches will be used as a fail safe mechanism for the linear actuators. This will allow for a safety in case of a system failure.

## **Setup Apache Webserver**

## **Develop Webpage and UI**

## **Test Linear Actuator**

The position of the linear actuator can be found from the resistance of a built in potentiometer. The resistance vs position curve needs to be found in order for accurate angle setting later on. Characteristics of the linear actuator may be used in the PI controller design later on as well.

## **Design Interface Circuitry**

The communication between the wind tunnel components and our microcontroller will require careful design. Relays and H-Bridges will be used for the majority of these applications.

## **Develop Controller Code**

## **Design PI Controllers**

PI controllers will be used for both speed and position control. Each of these controllers will have a unique set of characteristics that will need to be worked out to ensure proper function and the ability to meet our performance specifications.

**Develop Data/Control Server Application**

**Overall System Testing and Integration**

**Equipment List**

**Bibliography**