Implementing Remote Robotic System and Interface for Modal Analysis Remote Lab

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Abstract

It is more than a decade since Blekinge Institute of Technology introduced e-learning, remote laboratories and other innovative online learning solutions as a pedagogical education tool. The remote modal analysis lab is a remote lab project, which is a part of the university’s effort in the sound and vibration field. This project is developed and implemented for the bachelor degree in electrical engineering held at the Blekinge Institute of Technology, Karlskrona, Sweden.

The main aim of this thesis work is to implement a linear system with a cantilever beam, fixed on an isolated and a stable base and also provide a remote control facility to have more data acquisition in a nonlinear system. This facility is a robotic system, which has a remote control interface to support the needs of distance users to perform an experiment.

The remote robotic system project is divided into three parts:

- Implementing the base and fixing a cantilever beam.
- Designing and applying an electro-mechanical system (remote jack).
- Develop a control system software and an interface.
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# Acronyms and abbreviations

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<th>Description</th>
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<tbody>
<tr>
<td>A</td>
<td>Ampere</td>
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<td>cm</td>
<td>Centimeter</td>
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<td>DC</td>
<td>Direct Current</td>
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<td>EMI</td>
<td>Electromagnetic Interference</td>
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<td>F</td>
<td>Force</td>
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<td>g</td>
<td>Gram</td>
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<td>Ground</td>
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<td>Hz</td>
<td>Hertz</td>
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<td>IDE</td>
<td>Integrated Development Environment</td>
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<td>kg</td>
<td>Kilogram</td>
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<td>mA</td>
<td>Milliampere</td>
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<td>ms</td>
<td>Millisecond</td>
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<td>Megahertz</td>
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<td>N</td>
<td>Newton</td>
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<td>Ω</td>
<td>Ohm</td>
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<tr>
<td>PWM</td>
<td>Pulse Width Modulation</td>
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<tr>
<td>R</td>
<td>Resistance</td>
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<td>T</td>
<td>Ton</td>
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<td>V</td>
<td>Volt</td>
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1. Background

The combination of designed systems with demanded functionalities and theoretical control issues defines a field of engineering named, Control Engineering. In these modern days, with the help of the advanced technology, a new form of control engineering has been made a remarkable attention among the new generation of industry and academia.

The control engineering is a practical perform of the control theory. In addition, it is covering a wide area of control systems in our modern society. In other words, principals of control engineering understand the physical systems and mathematical models with considering different components and variables like inputs and outputs of the systems. Considering these principals and by use of latest technology and also by use of control systems design tools, engineers are going to develop and design a physical and tangible controller for the particular system. These systems can be any system in the area of mechanical, electrical, chemical, financial and even biological field.

Worldwide computer networks known as the Internet, is a miracle of the 21st century. The Internet is a part of a modern life today and it is hard for the Internet generation to imagine the world without it. This revolution growth fast in developed countries from 1991 and during last two decays this speed has grown hundred times to over one-third of the global population and has been infiltrated in all parts of human society and life like science, industry, art, media, politics, etc. The influence of the Internet in academia and industry is unstoppable and control engineering with the combination of the Internet has a great revolution in developing.

But before we go further, the significant role of sensors in the functional performance should be considered in closed-loop system in the control engineering. Collecting and measuring data and values from sensors can be used as a feedback for the input actuators so they can make a correction to the desired performance of the systems. It is called automatic control when a system can make a correction itself without any human inputs e.g. cruise speed control system in cars.
These days, e-learning, remote laboratories and other innovative online learning solutions, have been developed a lot to support the science education and it showed the integration and importance of the Internet in academia. In all over the world, the attitude of using and having a remote lab instead of traditional laboratory facilities with supervisors has been increased. There are much more benefits in remote laboratories such as less anxiety cause of sufficient time for working, therefore enhancing efficiency and experience quality and no risk for catastrophic failure. There will be less budget for preparing lab and facilities and there will be more participant regardless their physical locality, despite some disadvantages in setting up the equipment and debugging.

It is more than ten years since Blekinge Institute of Technology started to follow this trend and has been invested in remote labs as an academic field like the sound and vibration. In 2006 the university provided real equipment with remote accessibility with the title of “Vibration Analysis Of Mechanical Structures Over The Internet Integrated Into Engineering” [1]. The industry has a high attraction to experimental sound and vibration analysis and it is one of the most valuable tools for analyzing dynamic properties of the mechanical structure and with the help of these data, a product can be developed with required dynamic behavior [1]. In 2012 BTH decided to start a big project called “Remote Diagnosis” in collaboration with other universities and large companies e.g. Volvo, Saab, Ericsson, National Instrument, etc. The Remote Diagnosis project includes support from industry, the KKS foundation (Knowledge and competence foundation), research and higher education within the program expertise for innovation. The project involves developing industry, research institutes and university courses to strengthen the participating industries ability to build systems to remotely monitor, supervise and diagnose the functionality of their customer delivered products and design [2].

As a part of the Remote Diagnosis project, there has been a definition of a project that is a remote modal analysis lab. This remote modal analysis lab is divided into four parts as master and bachelor thesis works. The first part is to design and make a cantilever beam to get data in an ideal linear system. There is no definition for a system without inputs and outputs and they effected on each other. Linear system is a description of a dynamic system that has a linear differential equation relation between inputs and outputs. The second part of the remote lab is to design and program an interface with the help of the LabVIEW, for data acquisition. The third part is to program and create a web application for the remote lab. Finally, the last part is to implement the linear system with a cantilever beam fix on an isolated and stable base and provide a facility to have more data acquisition in a nonlinear system.
2. Objective

As an engineer, problems should be solved in an easiest and a best way with respect to the budget.

The main aim of this thesis work is to design, implement and add a remote electromechanical structure to the linear system and develop a prototype for the pedagogical part. This Robotic system must have a remote control interface to support the needs of distance users to perform an experiment. Adding this structure makes the system more capable of acquiring and analyzing more data. In simple terms, by installing the cantilever beam on an isolated, stable base, there will be an ideal linear system and by implementing the robotic system at the free side of the cantilever beam, it will be changed to a fixed beam or a linear system changed to a nonlinear one and vice versa in a dynamic system.

Nonlinear systems do not satisfy all the properties of superposition and homogeneity and also may have many balanced points. The principle of superposition does not necessarily apply for forced response for nonlinear systems.

There must be a consideration in design because of nonlinear system’s sensitivity, so this mechanical system has been designed separately and isolated from noises and distortion. The other significant point is stability for the separated system. Stability needs to be precisely defined for a nonlinear systems so the saddle must be designed as a heavy material.

With respect to the definition and all properties of the system, research question will be:

How can control an electrical jack, remotely?

The appropriate methods and researches are going to be described in the next step.
3. Design and implementation

3.1 Introduction

In this project (see figure 1), there will be a stable base (1) and the cantilever beam (2) as one structure, a shaker (3) and accelerometers (4) for data acquisition and a robotic system or an electro-mechanical system (5) to add an extra metal bar to the cantilever beam for changing the linear system to a nonlinear one, therefore, its changing characteristics.

Figure 1. The physical structure of the remote lab
There are some ideas to accomplish this project; moreover there are important points according to nonlinear system’s properties that must be considered in designing and implementing the robotic system such as:

- A nonlinear system is a sensitive system so there must be accuracy in design.
- There must be no noise in the system.
- The robotic system must meet the cantilever beam’s requirement.
- The system has to be stable, so there must be a stable base.

The process to reach the goal can be defined as follows:

- Implementing the base and fixing the cantilever beam.
- Designing and applying an electro-mechanical system (remote Jack).
- Writing a program as a control system software and interface.

There were researches and investigations for each of these steps.

### 3.2 Cantilever beam and the base:

#### 3.2.1 Introduction

This part of the project can be defined as a preparation for remote jack. It means that the cantilever beam must be installed on a massive base as one system that represents the linear system with linear characteristics.

#### 3.2.2 Cantilever beam:

As it can be seen in figure 2, this is the cantilever beam that has been designed and implemented as a thesis work called “Development And Implementation Of An Advanced Remotely Controlled Vibration Laboratory” [3]. Furthermore, it has eight holes that are suitable for M24 threaded rods. The length of each threaded rods is 670 mm to get into the cubic concrete base and to fix the cantilever beam. Criterias for designing this cantilever beam were:

- Having at least five resonance frequencies under 1000 Hz in the vertical direction [3].
- The effect of the transducers load on the beams dynamic properties below 1000 Hz may be considered negligible [3].
- Having the sufficient cross-sectional dimensions to enable magnetic attachment of adequate sub-structures [3].
There are some ideas for choosing this rectangular cross section cantilever beam, but the main reason is that the cantilever beam is a classic structure with easily understandable mode shapes. Also, such a structure may be modeled fairly accurately by using a one-dimensional Euler-Bernoulli beam [4].

3.2.3 Concrete base:
As mentioned before the base has to be stable and isolated, means there must be no signal interference. At first of the project, it was planned to has a minimum 1.5 T cubic concrete base with a metal frame protection. This frame is to protect edges of the base from deforming and damaging during rotation. In addition, it is a holder for the concrete framework. Another reason for choosing the frame is vibration. Long-term vibration, even little vibration will destroy the concrete. Armed concrete is a solution for this occurrence but reinforcing bars inside the concrete will cause signal distortion. This frame is going to keep the concrete stronger against vibration.

In meanwhile, a prebuilt cubic concrete discovered in the lab with the size of 65x65x60 cm, also with the frame and a hook on one side to get help for moving it. So this cube has been chosen to use by modifying and extending the size. With this consideration, there will be a less material and saving budget. This concrete will become so heavy after modification, so less rotation and less movement have to be considered. This cube had around 800 kg weight and by extending, up and down side for 20 cm of concrete and concerning concrete density, the weight will be more than 1.5 T, which is the ideal one.

Steps for modifying the concrete cube has been considered below:

1. Extending the frame vertically for 20 cm with a 3 x 3 cm square tube on both up and downsides, but first starting with the upper side that after
180-degree rotation will become the bottom. A 2.5 x 2.5 cm metal square tube has been put into 3 x 3 cm as an inside support, to have a strong joint between the old frame and a new one. Also, weld the junction to make the frame integrated. (2.5 mm Thickness for square tubes)

Figure 3. A squared metal tube inside the frame for supporting

2. A concrete framework has been made with wooden molds that have been cut and fixed on the metal frame. These woods are water resistance and they are especially designed for concrete frame working.

3. The surface of the old concrete has been rugged and has been covered with a primer. This is an established method to get more concrete cohesion.

4. A fresh concrete has been made (Coarse Cast C32/40) by 0-6 mm grain size. This is a ready mixture of concrete that is used for repairing, recasting and casting in constructions and it is best when required waterproofing and frost resistance. One 25 kg sack of concrete and three liters of water gives around 13 liters of the mixture [5].

5. This fresh concrete has been put in the framework up to 6 cm over the metal frame because the metal frame will reflect the vibration’s signal to the system and causes distortion. The fresh concrete has to be vibrated to have no air stuck in it and having a smooth surface.

6. It has been recommended at least one week of watering is enough but this process has been taken three weeks for the concrete base.

7. The cube was rotated for 180-degree after drying and put it on the wooden ERU-pallet. The pallet is an ordinary one but with one difference:
The place where the base has been located on the pallet, a wood sheet with the same size of the pallet has been installed so that it will be more supportive.

8. After rotation, steps 1-6 have been repeated for the other side and the only difference is that in step 5, the fresh concrete has to line up with the metal frame.

9. Eight vertical holes have been drilled with a Hilti Drill (DD200) and a core bit (28 mm diameter) for 50 cm depth. The diameter of the core bit has been calculated in user instruction of the chemical anchor including its thickness. The concrete chemical anchor has been filled in holes. Finally, eight M24 threaded rods with the length of 67 cm have been put inside the holes and letting them dry for 48 hours (Figure 4). These threaded rods are class 8.8 (tensile strength = 400 N/mm², yield strength 240 N/mm²) that has been marked with a yellow color as a color code on it.

10. The cantilever beam has mounted on the base and has been tightened with washers and nuts.
The final construction with its dimensions can be seen in figure 5.

Figure 5. The cantilever beam, fixed on the concrete base (linear system)

3.3 Electro-mechanical system (Remote jack):

3.3.1 Introduction
The main part of the thesis job is defined as an “electro-mechanical system” or a “remote jack.” The remote jack is a mechanism that is controlled remotely and it can provide a facility to have data acquisition for a nonlinear system. Physical components of the linear system consist of the cantilever beam, fixed on the concrete base, shaker and data acquisition sensors. The remote jack is installed on an adjustable table, which has been screwed on the pallet separate from the concrete base. The reason for placing this pallet is the same as for the concrete base. This pallet is going to isolate the remote jack system from outer signal disturbance and it is critical that the remote jack system has to be independent of the linear system.

When the remote jack has been activated and attached the metal bar to the cantilever beam, there will be a fixed beam proper for experiences in the nonlinear system. To ensure that each side of the cantilever beam is independent, when configured in the nonlinear mode, the remote jack and the
concrete base must have the maximum separation and isolation. To accomplish this job, the project divided into three sections: Jack and motor, Control box, Program and Interface.

![The remote jack system](image)

**Figure 6. The remote jack system**

**3.3.2 Jack and motor:**
To get started with this part there must be a definition of the method for converting the linear system to a nonlinear. The desired nonlinear lab experience can be accessible for the user by attaching a metal bar under the cantilever beam and making that side stable, so there will be fixed beam.

The other issue was the type of the movement and attaching method of the metal bar. There were two options available for this purpose, choosing a circular movement or choosing a vertical movement. The circular movement is the method that can be chosen when there is a space limitation or a specific definition for a particular location. Also there is more complexity in the circular movement and a solution for solving this complexity costs more budget. Also, there must be a powerful stepper motor or a DC motor with a gearbox to move
and attach a metal bar, which costs more and there is no knowledge for designing and making a proper gearbox.

Figure 7. A circular movement

The most natural and straightforward solution when it comes to vertical movement in the mechanical world is certainly any kind of jack. Different types of mechanical jacks are used in different designs according to the need and functionality. To implement the upward movement towards the end side of the cantilever beam, a jack is an ideal solution. It is possible to get proper force for tightening the metal bar.

A simple electro-mechanical scissor jack is the answer for our goal with some modification and adding parts. The parts of this development have been gathered in three groups and each group has specific tasks and specifications.

**3.3.2.1 Metal bar and touch brake support:**

The material that has been used in the cantilever beam is specified by SS-1672. In mechanical components, repeated loads and repeated stresses increases the risk for major consequences and cause most of the failures and collapses. This brings us to a term of mechanical fatigue, which is important in the mechanical testing of components. A construction steel SS-1672 is a steel that has 46 % carbon inside. Characterization of this stainless steel SS-1672 is performed with respect to tensile properties, fatigue properties, hardness and microstructure [6].

For the metal bar, construction has been made of stainless steel SS-1650 with the sizes of 100 x 60 x 20 mm, which is the second option for choosing the material. This bar has been attached to the scissor jack by a screw from the bottom.
Another important part is a square plate, which is a part of the emergency brake system and it is located under the metal bar. This plate is activating the upper micro switch in a case of system errors. In other words, if the jack went too high this plate is going to touch the micro switch and cut the electricity, so there will be no catastrophe.

3.3.2.2 Motor and gearbox:
The motor, which is equipped with the scissor jack, is a DC motor that is operated by 12V, DC power supply and 1A if loaded (max 2T). There is also a gearbox between the jackshaft and the motor with a small hole in it. In emergency cases, when there is no electricity, a small gray handle can be helpful for moving the jack up and down. A clockwise rotation will take the jack up and a counterclockwise rotation will move it down.

3.3.2.3 Emergency brake system:
Errors and failures are a part of any system, but they are not allowed to damage the system, so this system is therefore developed and added to prevent the cantilever beam and its base from serious damaging. The scissor jack has the power to lift a heavy mass like cars, with the maximum weight of 2T and even more so with this system there will be a need of a physical emergency brake.
system designed to define movement limitations for the remote jack. The emergency system is constructed in the simplest way, with the help of two, hinge lever type, micro switches, at scissor jack. These switches will break the circuit if the jack passes its limits. The upper switch is adjustable and it is located on a vertical threaded rod, besides the jack and it can be adjusted with the help of two nuts. This adjustment process has to be done visually and the position of the switch can be half of centimeter upper than a preferred position of the metal bar (support plate is a criterion) and the cantilever beam.

3.3.3 The control box:

3.3.3.1 Introduction
This is the control center of the remote jack, which is providing the Internet connection, user interface and making the jack functional. This control box consists of a box and a control unit. The protection for the system is a box made of durable, transparent plastic with the trademarked term Plexiglas. With 3 mm thickness and the size of: 2x(100 x 166 mm), 2x(100 x 80 mm), 1x(166 x 85 mm).

One of the advantages of the Plexiglas is impact resistance, so it is a good material to protect the components. The glue is known as “Plexi glue”, or “Acrylic glue”. This glue is melting into the free space between two Plexi parts so that the joint will be assembled into one piece. The front panel has been prepared and labeled for connections.

This control box has an inner part, which has been created with a combination of tree sections. These three parts are H-bridge, Pull down resistor and Arduino including an Ethernet shield.
Figure 10 shows the schematic of these three pieces linked with each other and with the scissor jack.

![Schematic of the control box and the jack](image)

Figure 10. A schematic of the control box and the jack

### 3.3.3.2 H-bridge:
H-bridges are popular for motor controlling. The main usages of H-bridge are in controlling the speed of a motor and the direction of the rotation. They can drive a current polarity that can be controlled by PWM (Pulse Width Modulation). The L298N Dual H-bridge Motor Controller module is compatible with Arduino and it can be used for two DC motors or control one bipolar stepper motor.

**Specifications:**

Max Power: 25 W  
Dimensions: 43 x 43 x 26 mm  
Weight: 26 g  
Double H-bridge Drive Chip: L298N  
Logical Voltage: 5V  
Drive Voltage: 5V-35V  
Logical Current: 0-36mA  
Drive current: 2A (Max single bridge)
For any pin on the H-bridge board, a number has been assigned that has a description.

**Note:** Red numbers has been used for controlling the remote jack.

![Figure 11. A dual h-bridge "L298N"](image)

1. DC Motor 1 “+” or Stepper Motor A+ (Motor Socket, Red).
2. DC Motor 1 “-” or Stepper Motor A- (Motor Socket, Blue).
3. 12V Jumper: This enables power to onboard 5V regulator. If using power supply voltage greater than 12V DC.
4. 12V power supply (<=35V): If the voltage is more than 12V remember to remove the 12V jumper (H-bridge Socket).
5. GND (H-bridge Socket).
6. 5V input or output.
8. IN1: Pin 8 Arduino.
9. IN2: Pin 7 Adriano.
10. IN3: Not used.
11. IN4: Not used.
13. DC Motor 2 “+” or Stepper Motor B+.
14. DC Motor 2 “-” or Stepper Motor B-.

### 3.3.3.3 FSR and pull down resistor:

Sensors have an important role in integrating modern technology into the world and they acts as translators between the physical environment and the digital world. The combination of a force sensor and the pull down resistor that is a part of a voltage divider as well will make the remote jack capable of getting feedbacks and calculating the right time for stopping the jack.
FSR (Force Sensitive Resistor):

There are many types of sensors and the desired output function from the system will affect in which type of sensor that should be chosen. The output of this project is defined by sensing the force when the metal bar attaches to the cantilever beam. The noise and the vibration are not affecting on the FSR’s sensitivity.

A force sensitive resistor is a sensor that converts a force (real world data) into an electrical signal that can be A/D-converted into understandable data for computers. The FSR provides: real pressure detection, compressing detection and weight detection. These sensors consist of polymer thick film (PTF) or conductive polymer, which Force has an inverse relation with resistance (figure 12). This characteristic between force and resistance is the reason for selecting a pull down resistor instead of a pulling up resistor. Because of that the pull-down resistor will be better to use as a part of the voltage divider. The reason is that the voltage from the voltage divider then will be a non-inverse function on the force.

![Figure 12. Force vs. resistance](image)

Another (equal) model is to focus on the conductance (inverse of resistance) to get the desired function. In figure 13, a linear scale explanation can be understandable with respect to the corresponding value of resistance on the right, vertical axis and the conductance value. The FSR conductance is directly proportional to the output voltage, which is generated by a simple circuit named
a current to voltage converter and it is helpful when linear response needed.

Figure 13. Force vs. conductance
A summary of description and dimensions will be found below:

Active Area: 1.5” [38.1] x 1.5” [38.1]
Nominal thickness: 0.018”[0.46 mm]
Material Build:
  Semi conductive Layer
  0.005” [0.13] Ultem
  Spacer Adhesive
  0.006” [0.15] Acrylic
  Conductive Layer
  0.005” [0.13] Ultem
  Rear Adhesive
  0.002” [0.05] Acrylic
Connectors
  1. No connector
  2. Solder Tabs (not shown)
  3. AMP Female connector [7]

Figure 14. A square FSR
All the sizes are in inches and millimeter.

**Active Area:** 24" [609.6] x 0.25" [6.3]  
**Nominal thickness:** 0.135" [0.34 mm]  
**Material Build:**  
- **Semi conductive Layer**  
  0.004" [0.10] PES  
- **Spacer Adhesive**  
  0.0035" [0.089] Acrylic  
- **Conductive Layer**  
  0.004" [0.10] PES  
- **Rear Adhesive**  
  0.002" [0.05] Acrylic  
- **Connectors**  
  No connector  
  Solder Tabs (not shown)  
  AMP Female connector [7]

Figure 15. A tail of FSR

The voltage divider is the suggested electrical circuit for making the sensor functional. A voltage divider or a potential divider is a fundamental circuit in electronics and it is used in many electrical applications. The purpose of using the voltage divider is to reducing the value of the input voltage and making it measurable for the microcontroller.

Figure 16. Force vs. voltage with respect to voltage divider
In a simple term, the input voltage will apply throw two resistors, which are connected in series. As it has been shown in the figure 16, the output voltage and force have a direct relation with each other so by increasing the force, the voltage is increasing as well. There will be a reverse relation by changing the place of $R_{FSR}$ and $R$. The current limitation throw the FSR is less than $1 \text{ mA/cm}^2$ of an applied force [7].

According to the voltage division formula, output voltage will calculated by:

$$V_{out} = \frac{V_{in} \times R}{R_{FSR} + R}$$

So:

- If $R_{FSR} = R \rightarrow V_{out} = \frac{V_{in}}{2}$
- If $R_{FSR} \ll R \rightarrow V_{out} \approx V_{in}$
- If $R_{FSR} \gg R \rightarrow V_{out} = 0$

Hence:

If chosen $R$ is much smaller than $R_{FSR}$, the output voltage would be near to zero and force sensitivity will be maximized. So the accepted value for the resistor is 100Ω.

The suggested op-amp is for single sided current. The low bias currents of these op-amps reduce the error due to the source impedance of the voltage divider [7]. This voltage divider circuit is also known as a pull-down resistor circuit.

**Pull down resistor:**

The pull-down resistor will be one of the resistors in the voltage divider, but normally it is used standalone at inputs of microcontrollers. A pull-down or a pull-up resistor circuit is used in case of open input pin(s) at a microcontroller or a microcontroller board. When using the word pull-up or pull-down, it means that the pin has been pulled up or down to a particular state or value if the input pin has no input voltage, which will be the case if $R_{FSR}$ will be very high which will happen when there is no force on the FSR sensor.

There was an experience by connecting the FSR sensor directly to the microcontroller with no pressure and checking for values. These values are a group of random numbers around zero. These random numbers or noises are because of a phenomenon is known as a floating. All input pins are floating if nothing is connected. This will make problems because the Arduino cannot detect any levels. The problem will increase due to EMI (Electro Magnetic Interference) radiations, especially from the electricity power network system.
(50 Hz/60 Hz). The best and easiest solution to avoid floating pin and to read the correct value over the serial input pin is to use a pull-up or pull-down resistor. The value of a pull-up or pull-down resistor will vary depending upon a specific device involved [8]. In the remote jack project, during the system operation, it is very critical to hold the logic signal near zero volts when no active command is given.

3.3.3.4 Arduino

“Arduino” is a brand name and it has many models. The Arduino was created at the Ivre a Interaction Design Institute as an easy tool for a fast prototyping, aimed for students without any background in electronics and programming [9].

Various models of the Arduino are available depending on the budget and the number of pins. The popular model of the Arduino is the Arduino Uno, which is the most widely distributed device. The hardware itself is an open source design and all components are off the shelf, means anyone can freely copy the design and sell their brand or a derivative product. In fact, you make your own Arduino just by purchasing all the components individually. In that sense, the Arduino is nothing unique but it is the combination of hardware, software and the community rounded which makes the Arduino special.

Well in the past, if you wanted to make something electronic at least it was necessary to educated in that field or limited to a single project but with the help of microcontrollers, making something complex with relatively few lines of code has become very comfortable.

Figure 17. Arduino pin mapping
Therefore, the Arduino is a rapid prototyping tool. In the short time, you can make some awesome things really quickly. Some advantages of this board are listed below:

- Low cost
- Not a limited platform. It can be installed on Windows, Mac and Linux
- User-friendly integrated development environment (IDE)
- Simple coding
- Open source program and software
- Open source hardware

The heart of the Arduino is a microcontroller (ATmega328P, Atmel company), which can be described as a programmable small computer that can do different things. There is also a timing crystal, a power regulator and a USB interface.

![ATmega328p pin out](Figure 18. ATmega328p pin out)
Sets of input and output pins are located along the sides. One side has pins for a
digital input and output and another side has analog ones. Each of these pins can
be programmed as either an input or output and the status can be on or off (low
or high). A few of these digital pins are special and called PWM (Pulse Width
Modulation) and they are indicated by a little wave line next to the pin number.
Other pins have 3.3V and 5V power connections, the ground line and also five
analog inputs. These analog pins are only inputs and they will connect to a device
like: microphone, light sensor, force sensor and any devices that give a range of
outputs and generate an analog signal. The FSR sensor is connected to A0 pin.

The layout of these pins is standardized, which means you can buy upgrades of
additional functionality called “Shields” These shields are mounted on the
Arduino and work together as a one device like the official Ethernet with SD card.
This Arduino Ethernet shield gives a network access for the project and
additional storage space. Used pins on the Arduino Ethernet shield are marked
and explained in figure 19.

![Arduino Ethernet shield and connections](image)

**Figure 19. Arduino Ethernet shield and connections**

There is a small debug LED built in the Arduino on pin 13 that can be used for
testing the program quickly when there is no need of connecting an external
LED. Furthermore, the Arduino has built in a pull-up resistor and it can be easily
available by a command.

### 3.4 Program and interface:

#### 3.4.1 Arduino’s software:
The open source Arduino software or Integrated Development Environment (IDE) provides an easy way to program and upload codes to the microcontroller
The Arduino platform gives you many prewriting functions and predefined libraries, so coding is not complicated. In addition, it can be installed on Windows, Mac OS and Linux operating systems.

The codes for remote jack are written in an easy and understandable way. The first thing to start working with Arduino is downloading and installing the Arduino software package from the website [www.arduino.cc](http://www.arduino.cc) on a proper platform. Furthermore, to connect the Arduino board to a computer for uploading, debugging and verifying codes, a USB A to B cable (printer cable) is needed also. A small green LED should blink, after connecting the board to the computer.

The USB cable powers the Arduino board. For the Arduino board working consistently, it has to be attached to a 7-12V-power supply. After downloading the Arduino software, the interface of the application should be like below.

An initial setup has to be done for a newly installed computer.

The first step is to specify the environment and the board, by selecting the tools menu and select the board. The second step is to choose the right serial port by selecting the tools menu and click on Port and choose (/dev/cu.usbmodemFA131).
As it shown in figure 20, there are three important buttons. The “Serial Monitor” button is working as a terminal that can communicate by receiving and sending serial data. Serial Monitor is a great facility to controlling and debugging codes. The “Verify” button is to compile and check for errors. Finally, after finishing with codes, it can be easily uploaded to the microcontroller with the “Upload” button.

3.4.2 Arduino’s program

Programs in the Adriano are called Sketches. The Arduino syntax is similar to C++. In addition, it provides many predefined functions, which simplifies the programming experience in particular for inexperienced users.

Each sketch has two parts or two void type functions (void function does not return any value): void setup() and void loop(). All the initialization codes and all the instructions that needs to be run once after powering up the Arduino should be in the setup() and all repeatable codes have to be written in the loop().

Moving Up
Boolean function= False

Figure 21. Moving up algorithm

The process of coding has been divided into smaller tasks to make the programming more logical. The expected output of the program is a two-direction action or function, moving up and down. In the next step, these movements will accessible through the Internet.
Each action has an algorithm, which can be considered in figure 21 and figure 22. A Boolean can be a great pickup function for defining each action as a true or false state. Each flowchart describes a sequence of operations for moving up and down.

**Figure 22. Moving down algorithm**

As mentioned before, an easy and practical work has been taken into consideration. In order to follow this purpose when coding, two important variables are defined in the first lines of the program:

**nTightValue:** When the jack is raised to its maximum height, it will be finally touch the cantilever beam. This “nTightValue” is the value that indicates how tight the metal bar must be, to convert the cantilever beam to the fixed beam. The value represents the force between the metal bar on the top of the jack and the cantilever beam.

**nDelay:** This is the time duration for the remote jack to go down. The unit of this variable is milliseconds.

Finally, the HTML codes have been written for a simple web page with two push buttons: one button for moving up (Nonlinear system) and one button for moving down (Linear system).
There are also individual programs for maintenance like testing the FSR sensor or moving the jack up and down without an Internet connection.

4. Result, conclusion and future work

4.1 Result
The current interface of the remote jack is shown in figure 23. This web page will be added to the final experimental page of the main server. The two pushbuttons represent the linear mode and the nonlinear mode respectively.

![Remote Lab Project](image)

Figure 23. The remote jack control interface

The remote jack project requires some configuration to work properly.

- **Level the metal bar**: The metal bar has to be leveled with respect to the cantilever beam in two directions at least (preferred X and Y axis). This leveling has to be done with the help of three screws that are located at the bottom of the scissor jack and a digital level tool.

- **Set emergency switches**: As mentioned before there are two switches. One of them is fixed on the jack’s body and another one is on the brake holder, which is adjustable with the help of two nuts. The switch can be a half centimeter above the maximum preferred position of the metal bar with respect to the cantilever beam. In emergency situations, electricity power will be turned off. Use the special gray handle to bring down the jack or free the upper switch with the help of two nuts.
• **Internet connections:** The Internet connection has to be checked between a network socket and the router and also from router to the Arduino.

• **Main connections on the Control Box:** There are five connections excluding the FSR sensor connection, locate on the front panel of the control box. The wires have to be connected to the corresponding labels. Additionally, the FSR sensor has to be fixed to the wire, which is connected to the pull-down resistor.

• **Arduino connections:** It should be ensured that Arduino, H-Bridge and pull-down resistors are correctly connected to each other.

• **Connect the Arduino to a computer with the cable and open the Arduino IDE (Integrated Development Environment).**

• **The WebSketch program:** The name of the main program is “WebSketch.” This program has to be uploaded to the Arduino board and it will be saved in the memory for the first time. Initial values (nTightValue & nDelay) have to be considered in the first lines of the codes. Compiling and uploading are the two next steps and at the end, the functionality of the remote jack can be tested through the web interface.

A remote robotic system and interface for the modal analysis Lab is implemented and tested fine. This system provides a new opportunity for students to perform experimental and analysis in both linear and nonlinear systems. Therefore there are two requests (Linear or Nonlinear) available for the user on the web page.

The user interface is a HTML page, which is accessible through the Ethernet shield. The Ethernet shield is providing an IP address for the HTML page to provide communication over the network. The final test of the remote jack is to connect the university LAN (Local Area Network) so the Ethernet shield obtains an IP address by using DHCP protocol. This IP address can be randomly provided so it has to be checked through the serial monitor window in the Arduino’s software. In future, a computer server will be responsible for the availability of HTML page over the WAN (Wide Area Network) and the Ethernet shield will be add as a client to the server. There is also a possibility to reserve a public IP address for the web page but it has to be investigated and also it costs.

**4.2 Conclusion**

The test is started by opening a browser and writing the provided IP address in the address bar. Figure 24 shows the schematic of sending a request: linear or nonlinear.
Figure 24. A schematic of sending a request

When the HTML page is reachable, it means that the connection between a user, network (LAN) and the remote lab has been successfully established. By clicking on the “Linear” button (GET request), the user sends this request to the Ethernet shield through the university LAN. The Ethernet shield is a network device, which is communicating either to a client (requesting information) or to a server (providing information). The Ethernet shield will provide the information by asking the Arduino Uno (microcontroller) to execute the proper codes. In the Arduino, the “Linear” request is defined by the “Moving Down” algorithm (Figure 22). The Arduino controls the status of the FSR by checking the analog sensor, pin A0 that is connected via the pull down resistor module. If the value of the pin A0 shows that the metal bar is connected to the cantilever beam (value>0), according to the flowchart in figure 22, the microcontroller will send digital values to the H-bridge via digital pin 7 and digital pin 8 (Pin8=0, Pin7=1). Then the H-bridge converts these values and sends them to the DC motor. Hence the jack will decrease its height slightly for five seconds.

For setting the remote jack in a nonlinear position (sending “Nonlinear” request), the jack will increase the height of the metal bar so it will touch the cantilever beam with a pre-defined force and the microcontroller will consider the “Moving Up” algorithm (Figure 21). Values for digital pins will also be vise versa (Pin8=1, Pin7=0).

4.3 Future work

There are also plans for developing and expanding this lab. Adding or changing the object can be the first idea for creating more complex test object. Now, the cantilever beam is the test object and it can be replaced by T shape beam with I cross-section or a plate. New objects can also be added beside the cantilever beam to have simultaneous data acquisition. Adding extra web facilities such as IP cameras to the final lab interface could give the sensation of a real lab environment. Furthermore, a robotic arm can be added to the whole system to bring and attach different combination of mass and spring at the determined position of the test object.
5. References


Accessible at: 2017-06-06


Accessible at: 2017-06-06


Accessible at: 2017-06-06

http://playground.arduino.cc/CommonTopics/PullUpDownResistor
Accessible at: 2017-06-06

Accessible at: 2017-06-06
Appendix I

Remote Robotic System and Interface for Modal Analysis Remote Lab: Instructions

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1. Acronyms and abbreviations

A  Ampere
DC  Direct Current
EMI  Electromagnetic Interference
g  Gram
GND  Ground
Hz  Hertz
MHz  Megahertz
mA  Milliampere
mm  Millimeter
ms  Millisecond
Ω  Ohm
PWM  Pulse Width Modulation
R  Resistance
T  Ton
V  Volt
W  Watt
2. Introduction

This booklet is an instruction for setup, operation and troubleshooting of the “Remote Robotic System”. This system is called “Remote Jack” in this booklet for easy remembering and to prevent confusion. This remote jack is added to the remote modal analysis lab structure for acquiring and analyzing data in both linear and nonlinear systems. In other words this jack converts a linear system to a nonlinear one by attaching a metal bar to the main cantilever beam, remotely.

The remote jack system is divided into three parts: jack and motor, control box, program and interface.

![Figure 1. The remote jack](image)

**Note:** Information in each part of this instruction is not detailed. If you need so, please read the complete report.
3. Jack and motor

The mechanical part of the remote jack is a simple electric scissor jack that has been modified and developed towards our goal.

![Diagram of a scissor jack](image)

**Figure 2. Developed scissor jack**

The developed scissor jack has some parts that are listed below:

3.1 Metal bar and touch brake support:
The metal bar is a construction stainless steel specified by SS-1650 with the sizes of 100 x 60 x 20 mm, which has been attached to the jack by a screw from the bottom. There is also a square plate located between the bar and the jack’s body. This plate is a part of the emergency brake system and it is activating the upper micro switch in a case of system errors. In other words, if the jack went too high, this plate will touch the micro switch and then the scissor jack will be switched off.

**Attention:** For maintenance and replacing consider the minimum designed size of the bar is 100 x 50 x 10 mm and the material should be either SS-1650 or SS-1672 (the same material as the cantilever beam).
3.2 Motor and gearbox:
The motor is a DC motor that is operated by 12V, DC power supply and 1A if loaded (max 2T). There is also a gearbox between the jackshaft and the motor with a small hole in it. In emergency cases, when there is no electricity, remove the cap of the hole and use a special small gray handle for moving the jack up and down. A clockwise rotation will take the jack up and a counterclockwise rotation will move it down.

![Figure 3. Gray handle](image)

3.3 FSR (Force Sensitive Resistor):
Force sensitive resistors (FSR) provide physical pressure detection, compressing detection, and weight detection. These sensors consist of polymer thick film (PTF) or conductive polymer which force varies inversely with resistance. This characteristic caused to select pull down resistor instead of pulling up resistor in the voltage divider. FSRs are suitable for inaccurate measurement. However, in this project the exact force is not important.

![Figure 4. Force vs. resistance](image)
If there is a problem with the sensor or if the sensor is broken, it has to be replaced with a new one.

A summary of description and dimension will be found below.

![Diagram of Square FSR](image)

**Active Area:** 1.5” [38.1] x 1.5” [38.1]  
**Nominal thickness:** 0.018” [0.46 mm]  
**Material Build:**  
- **Semiconductive Layer**  
  0.005” [0.13] Ultem  
- **Spacer Adhesive**  
  0.006” [0.15] Acrylic  
- **Conductive Layer**  
  0.005” [0.13] Ultem  
- **Rear Adhesive**  
  0.002” [0.05] Acrylic  
**Connectors**  
1. No connector  
2. Solder Tabs (not shown)  
3. AMP Female connector

*Figure 5. Square FSR*

### 3.4 Emergency brake system:
This system is developed and added to prevent the cantilever beam and its base from serious damaging. The scissor jack has the power to lift a heavy mass with the maximum weight of 2T and even more so with this system there will be a need of a physical emergency brake system designed to define movement limitation for the remote jack.

There are two hinge lever types, micro switches, at the scissor jack. These switches will break the circuit if the jack passes its limits. The upper switch is adjustable and it is located on a vertical threaded rod, beside the jack and it can be calibrated with the help of two nuts. The calibration process will be explained in the setup and operating section.
4. Control box

A box made from strong, transparent plastic with the trademarked term Plexiglas, with 3 mm thickness. One of the advantages of this material is impact resistance. The glue is known as "Plexi glue", or “Acrylic glue”. This glue is melting into the free space between two Plexi parts so that the joint will be assembled into one piece. The front panel has been prepared and labeled for connections. This control box has an inner part, which has been created with a combination of tree sections. These three parts are H-bridge, Pull down resistor and Arduino including Ethernet shield.

![Control box](image)

*Figure 6. Control box*

4.1 H-bridge

The main usage of a H-bridge is to control the speed and rotation direction of a motor. A H-bridge also can drive a current polarity that can be controlled by PWM (Pulse Width Modulation). The L298N Dual H-bridge Motor controller module is compatible with the Arduino and it can be used for up to two DC motors or two stepper motors.

A small red LED will turn on by connecting to the power.
For any pin on the H-bridge board, a number has been assigned that has a description.

![Dual H-bridge L298N](image)

*Figure 7. Dual H-bridge L298N*

1. DC Motor 1 “+” or Stepper Motor A+ (Motor socket, red)
2. DC Motor 1 “-” or Stepper Motor A- (Motor socket, blue)
3. 12V Jumper: This enables power to onboard 5V regulator. If using power supply voltage greater than 12V DC.
4. 12V power supply (<=35V): If the voltage is more than 12V remember to remove the 12V jumper (H-bridge socket).
5. GND (H-bridge socket).
6. 5V input or output.
8. IN1: Pin 8 Arduino.
10. IN3: Not used.
11. IN4: Not used.
13. DC Motor 2 “+” or Stepper Motor B+
14. DC Motor 2 “-” or Stepper Motor B-

**Note:** Red numbers has been used for controlling the remote jack.
Specifications:

Max Power: 25 W
Dimensions: 43 x 43 x 26 mm
Weight: 26 g
Double H-bridge Drive Chip: L298N
Logical Voltage: 5V Drive Voltage: 5V-35V
Logical Current: 0-36mA Drive current: 2A(Max single bridge)

4.2 Pull down resistor
One of the most important things when working with Arduino and such boards is that all input pins are floating if nothing is connected. This will make problems because of the Arduino can not detect any levels. The problem will increase due to EMI radiations, especially from the electricity power network system (50 Hz or 60 HZ). The best and easiest solution to avoid floating pin in microcontrollers and to read the value over the serial input pin is to use a pull up or a pull down resistor.

As mentioned before in the FRS section, force has an inverse relation with resistance so using the pull down resistor is recommended. Because of that the pull down resistor will be one of the resistors in the voltage divider. The value 100 Ω of the pull down resistor has been selected to get a suitable voltage level to the input pin.

![Pull down resistor diagram](image)

*Figure 8. Pull down resistor*

If needed the value of the resistance is 100 Ω, which can be replaced by another value using a soldering method. On the physical circuit, FSR connections are soldered on breadboard but connections on the Arduino side are replaceable.
**Note:** The Arduino already has a built in pull up resistor. In any case of use, the built in pull up resistor, please change the “INPUT” to “INPUT-PULLUP” in all program codes.

### 4.3 Arduino

Two Arduino boards are combined together to provide jack controlling through Internet. These Arduino boards called: “Arduino Uno Rev3” and “Arduino Ethernet Shield”.

The Arduino Uno Rev3 is a microcontroller based board. The heart of the Arduino is a microcontroller (ATmega328P), Atmel Company, which can be describe as a programmable small computer that can do different things. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, an ICSP header and a reset button. It contains everything needed to support the microcontroller. Simply connect it to a computer with a USB cable or support it with an adapter. [https://www.arduino.cc/en/Main/ArduinoBoardUno](https://www.arduino.cc/en/Main/ArduinoBoardUno)

![Figure 9. Arduino Uno Rev 3](image)

The Arduino Ethernet Shield allows an Arduino board to connect to the Internet. It is based on the Wiznet W5100 Ethernet chip. The Wiznet W5100 provides a network (IP) stack capable of both TCP and UDP. It supports up to four simultaneous socket connections. The Ethernet shield connects to an Arduino board using long wire-wrap headers, which extend through the shield. This allows another shield to be stacked on top. There is an onboard micro-SD card slot, which can be used to store files for serving over the network.
The Ethernet shield is placed on the top of the Arduino Uno and then all connections between H-bridge, Arduino and Pull down resistor board must be assign to their proper place according to figure 10 and board labeling on device. Remember to check all three main connections: LAN, USB (just for programing the Arduino and show running program) and Arduino power supply, on the box.

5. Program and interface

5.1 Arduino software
The open source Arduino software or integrated development environment (IDE) provides an easy way to program and upload to the microcontroller. Programming the Arduino is not complicated because the Arduino platform gives you many prewriting functions and predefined libraries. In addition, it can be installed on Windows, Mac OS and Linux operating systems.

The application for the remote jack has been written in an easy and understandable way. To start working with the Arduino; first download and install the Arduino software package from the web site www.arduino.cc for your operating system. Second, there must be a USB A to B cable (printer cable) available to connect the Arduino board to the computer for uploading, debugging and verifying codes. A small LED should blink, after connecting the board to the computer.
Note: The USB cable powers the Arduino board otherwise, it has to be connected to a 7-12V-power supply.

After downloading the Arduino software, the interface of the application should be like figure 11. This is where the codes are typed, compiled and sent to the Arduino board.

![Arduino Software](image)

*Figure 11. Arduino Software*

An initial setup has to be done for a newly installed computer. The first step is to specify the environment and board by selecting the tools menu and select the board, Arduino Uno. The second step is to choose the right serial port by selecting the tools menu and click on Port and choose (/dev/cu.usbmodemFA131).

As shown in figure 11 there are three important buttons. The “Serial Monitor” button is working as a terminal that it can communicate by receiving and sending serial data. Serial Monitor is a great facility to debugging codes. The “Verify” button is to compile and check for error. Finally, after finishing with codes, it can be easy uploaded to the microcontroller with the “Upload” button.
5.2 Arduino’s program
Programs in Adriano are called Sketches. The Arduino syntax is similar to C++. In addition, it provides many predefined functions, which simplifies the programming experience in particular for inexperienced users. Each sketch has two parts or two void type functions (void function does not return any value): void setup(), void loop(). All the initialization codes and all the instructions that needs to be run once after powering up the Arduino, should be in the setup() and all repeatable codes have to be written in loop().

It has been considered that if someone does not have the knowledge of programming can work with the remote jack system and make the remote jack functional. In order to follow the purpose of a practical working with the remote jack, two important variables are defined in the first lines of the program:

nTightValue: When the jack is raised to its maximum height, it will be finally touch the cantilever beam. This “nTightValue” is the value that indicates how tight the metal bar must be, to convert the cantilever beam to the fixed beam.

nDelay: This is the time duration for the remote jack to go down. The unit of this variable is (ms).

Note: There is no need to writing the codes here in the instruction. To get access to the codes ask for the thesis report or the remote jack flash memory.

The current interface of the remote jack is shown below.

![Remote Lab Project](image)

*Figure 12. Remote jack control interface*
6. Setup and operating

To setup the remote jack before operating, one must perform the checklist below. The list has been prepared with some explanations to make the system’s functionality, easier and faster to understand.

- **Level the metal bar:** The metal bar has to be leveled with respect to the cantilever beam in two directions at least (preferred X and Y axis). This leveling has to be done with the help of three screws that are located at the bottom of the scissor jack and a digital level tool.
- **Set emergency switches:** As mentioned before there are two switches. One of them is fixed on jack’s body and another one is on the brake holder, which is adjustable with the help of two nuts. The switch can be a half centimeter above the maximum preferred position of the metal bar with respect to the cantilever beam. In emergency situations, electricity power will be turned off. Use the special gray handle to bring down the jack or free the upper switch with the help of two nuts.
- **Internet connection:** The Internet connection has to be checked between a network socket and the router and also from the router to the Arduino. If a new router will be replace by an old one, the MAC address has to be verified by IT Help desk.
- **Main connections on the Control Box:** There are five connections excluding the FSR sensor connection, locate in the front panel of the control box. The wires have to be connected to corresponding labels. Additionally, the FSR sensor has to be fixed to the wire, which is connected to the pull-down resistor.
- **Arduino connections:** It should be ensured that Arduino, H-bridge and pull-down resistors are correctly connected to each other.
- **Connect the Arduino to a computer with the cable and open Arduino IDE (Integrated Development Environment).**
- **The WebSketch program:** Open WebSketch file, set initial values (nTightValue & nDelay), compile if necessary and upload it to the board and check the functionality of the remote jack.

**Note:** There are three more programs available for troubleshooting. They are: UnoSketch (for running the whole system without available Internet and web interface), SensorReadSketch (for checking the value of sensor and sensor’s functionality) and UpAndDownSketch (for moving the jack up and down).
Appendix II

Remote Robotic System and Interface for Modal Analysis Remote Lab: Software

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1. Introduction

The Arduino syntax is similar to C++. In addition, it provides many predefined functions, which simplifies the program development, especially for inexperienced users.

The programs in the Adriano are called “Sketches”. Each sketch is divided into two parts and consist of two void type functions (a void function does not return any value): void setup(), void loop(). All the initializations and all the things that need to be run once after powering up the Arduino should be coded in the setup() and all repeatable codes have to be written in the loop().

The remote lab project has one main program and three individual maintenance programs for testing and trouble shooting purposes.

2. Main program (WebSketch)

2.1 Introduction

The name of the main program is “WebSketch”. This program has to be uploaded to the Arduino board for the first time and it is saved in Arduino memory. Initializing values (nTightValue & nDelay) have to be considered in the first lines of the code. Compiling and uploading are the two next steps and at the end, the functionality of the jack can be tested through the web interface.

2.2 WebSketch codes

As mentioned before, easy and practical work has been taken into consideration.

For following this purpose in coding, two important variables have been defined at the first of the program:

**nTightValue**: When the jack will increase its height, it will be finally touch the cantilever beam. This “nTightValue” is the value that indicates how tight the metal bar must be to convert the cantilever beam to the fixed beam.

**nDelay**: This is the time duration for the remote jack to go down. The unit of this variable is milliseconds.
/* WebSketch
Arduino with Ethernet Shield.
To control the remote jack with web based interface.
*/

#include <SPI.h>

#include <Ethernet.h>

int sensorPin = A0;     //Analog pin (A0) connected to FSR sensor
int sensorValue = 0;    //Initial value of FSR sensor
int nTightValue = 50;   //Tightness of metal bar with cantilever beam
int nDelay = 5000;      //Time duration of jack move down (ms)

byte mac[] = { 0x90, 0xA2, 0xDA, 0x0E, 0xAF, 0x21 }; //Physical mac address
EthernetServer server(80); //Communication Server port to find HTTP server
String readString;                  //Type (String) of readString

void setup()
{
  pinMode(7, OUTPUT);  //Pin7 Arduino set as an output
  pinMode(8, OUTPUT);  //Pin8 Arduino set as an output
  Serial.begin(9600);//Open serial communications and sets data rate to 9600
                     //bps
  while (!Serial)
  {
  //Wait for serial port to connect.
  }

  if (Ethernet.begin(mac) == 0)       //Start the Ethernet connection
  {
    Serial.println("Failed to configure Ethernet using DHCP");
    for (;;)           //No point in carrying on, so do nothing forevermore
  ;
  }

  Serial.print("My IP address: ");
  for (byte thisByte = 0; thisByte < 4; thisByte++)
  {
    Serial.print(Ethernet.localIP()[thisByte], DEC);
    Serial.print(".");
  }
  Serial.print(".");

  //Print your local IP address in decimal form on serial monitor window:
  Serial.println("server is at ");
  Serial.println(Ethernet.localIP());
}
/Main code here, to run repeatedly:

```cpp
void loop()
{
    sensorValue = analogRead(sensorPin);//Read the value of the sensor input

    // Create a client connection:
    EthernetClient client = server.available();
    if (client)
    {
        while (client.connected())
        {
            if (client.available())
            {
                char c = client.read();

                // Read char by char HTTP request
                if (readString.length() < 100)
                {
                    readString += c; //store characters to string
                }
            }

            // If HTTP request has ended
            if (c == '\n')
            {
                Serial.println(readString); //Print to serial monitor for debugging
            }
        }
    }

    // Send new page and HTML page for client:
    client.println("HTTP/1.1 200 OK");
    client.println("Content-Type: text/html");
    client.println();
    client.println("<HTML>");
    client.println("<HEAD>");
    client.println("<meta name='apple-mobile-web-app-capable' content='yes' />");
    client.println("<meta name='apple-mobile-web-app-status-bar-style' content='black-translucent' />");
    client.println("<link rel='stylesheet' type='text/css' href='http://randomnerdtutorials.com/ethernetcss.css' />");
    client.println("<TITLE>Remote Lab Project</TITLE>");
    client.println("</HEAD>");
    client.println("<BODY>");
    client.println("<H1>Remote Lab Project</H1>");
    client.println("<hr />");
    client.println("<br />");
    client.println("<br />");
    client.println("<a href="/?linearOn""> Linear </a>");
    client.println("<br />");
    client.println("<br />");
    client.println("<a href="/?linearOff"">Nonlinear</a>");
    client.println("<p>Created by Faramarz Erfanian.</p>");
```
client.println("<br />");
client.println("</BODY>");
client.println("</HTML>");

delay(1); // Give the web browser time to receive the data
client.stop(); // Stopping client

/*-------------------Push buttons functions-------------------*/

if (readString.indexOf("?linearOn") > 0)
{
    if (sensorValue != 0)
    {
        MoveDown();
        delay(nDelay);
        StopMove();
    }
    else
    {
        StopMove();
    }
}

if (readString.indexOf("?linearOff") > 0)
{
    if (sensorValue == 0)
    {
        MoveUp();
        while (sensorValue < nTightValue)
        {
            sensorValue = analogRead(sensorPin);
        }
        StopMove();
    }
    else
    {
        StopMove();
    }
    readString = "; // clearing string for next read
}

// Upward movement function:
void MoveUp()
{
    digitalWrite (8, HIGH);
    digitalWrite (7, LOW);
}
3. Testing and trouble shooting programs

3.1 Introduction

During the time of development the system, there were some programs originally developed for testing the equipment like the scissor jack and the FSR sensor. Furthermore, there is a program for testing the performance of the remote jack system. After finalizing the project, these three simple programs have been grouped for testing purpose and troubleshooting the system in future. These applications are listed below:

- Application 1 (UnoSketch): This program is for checking the performance of the remote jack system without any Internet connection.

- Application 2 (SensorReadSketch): This simple application is for testing the value of the FSR sensor through the serial monitor window.

- Application 3 (Up_and_downSketch): This program will move the jack up and down when the sensor is not working.

3.2 Application 1 (UnoSketch)

/*UnoSketch
 Arduino without Ethernet Shield.
 To test the functionality of the remote jack with no Internet connection.
 By Making the Boolean function “true” or “false” The jack can be tested.
 */

int sensorPin = A0; //Analog pin (A0) connected to FSR sensor
int sensorValue = 0; //Initial value of FSR sensor
boolean bLinearity = false; //direction of moving the arm (Linear or Nonlinear)
int nTightValue = 50; //Tightness of metal bar with cantilever beam
int nDelay = 5000;          //Time duration of jack move down (ms)

// Setup code here, to run once:
void setup()
{
  pinMode(7, OUTPUT);  //Pin7 Arduino set as an output
  pinMode(8, OUTPUT);  //Pin8 Arduino set as an output
  Serial.begin(9600); //Open serial communications and sets data rate to 9600  // bps
}

//Main code here, to run repeatedly:
void loop()
{
  sensorValue = analogRead(sensorPin);      //Read the value of the sensor
  Serial.print("initial sensor value: ");   //Description for a printed value
  Serial.println(sensorValue);              //Print the value
  // Boolean conditions and functions:
  if (bLinearity)
  {
    if (sensorValue == 0)
    {
      MoveUp();

    while (sensorValue < nTightValue)
    {
      sensorValue = analogRead(sensorPin);
      Serial.print("sensor value in the while loop MoveUp: ");
      Serial.println(sensorValue);
    }
    StopMove();
    }
  }
  else
  {
    if (sensorValue != 0)
    {
      MoveDown();

      delay(nDelay);
      StopMove();
    }
  }
  // Upward movement function:
  void MoveUp()
  {
    digitalWrite (8, HIGH);
    digitalWrite (7, LOW);
  }
3.3 Application 2 (SensorReadSketch)

/* SensorReadSketch
Read the Sensor and print the value.
This is a program for checking the sensor value throw serial print window.
*/

int fsrPin = A0;       //Integer data type and assign to A0 pin
int fsrReading;        //Integer data type

// Setup code here, to run once:
void setup()
{
    Serial.begin(9600);  //Open serial communications
}

//Main code here, to run repeatedly:
void loop(void)
{
    fsrReading = analogRead (fsrPin);// Read the analog value of the FSR input

    Serial.println("Analog reading = "); //Description for a printed value
    Serial.println(fsrReading);        //Print the value
    delay(100);                        //Delay of each print on serial monitor window
}

3.4 Application 3 (Up_and_downSketch)

/*Up_and_downSketch
To move the jack up or down in case that just needed to move the jack.
If any movement chooses the other unnecessary function has to be selected as a comment.
*/

// Setup code here, to run once:
void setup()
{  pinMode(7,OUTPUT);  //Pin7 Arduino set as an output
  pinMode(8,OUTPUT);  //Pin8 Arduino set as an output  
}

//Main code here, to run repeatedly:
void loop()
{
  // Up:
  digitalWrite (8,HIGH);
  digitalWrite (7,LOW);

  //Down:
  digitalWrite (7,HIGH);
  digitalWrite (8,LOW);

}

Note: For information about installing libraries visit the web site: