NI POLLUTION MONITORING AND WEATHER STATION CONTEST FINAL REPORT

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ABSTRACT

This document is part of partial fulfillment of the NI-project to utilize wireless nodes to build a weather station. The participating team is composed of 5 members who represent Texas A&M University. The team has successfully met the minimum requirements and built a wireless weather station. Utilizing LabVIEW and the wireless nodes provided by National Instruments, the weather station is capable of monitoring the following multiple weather parameters, including: temperature, pressure, rain, radiation, humidity, wind speeds and direction. In addition to the monitoring feature, the system can process the data and is capable of alerting the end-user if certain monitored parameter(s) exceed the threshold values and reach dangerous levels. A third feature is that the system is capable of logging the data for further processing if needed.

The team has faced some challenges. One of the challenges is logistical limitation in obtaining the gas sensors. Nevertheless, the team has searched and identified the appropriate sensors and has designed the system accordingly. Another challenge involved building the prediction method. The team has identified few models and described one of them in this report but could not include it as part of the weather station system in time.

The team believes that this project should not stop here and future plans for this weather station are already in motion. Examples of further prospects may comprise of gathering weather data and comparing multiple weather forecasting models, controlling watering systems for agricultural applications, and building multiple weather stations to construct a metrological profile for areas of interest. The number of plans and projects enabled by this type of technology is limitless.
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INTRODUCTION

This paper discusses the implementation, design and the data analysis techniques in a Weather Station model. This document is being submitted as the final paper for the project competition “NI Pollution Monitoring and Weather Station Contest” being organized by the National Instruments. The main objective of the report will be to clearly outline the procedure followed, the instruments utilized in the project, measurement of each quantity, representation of data collected in appropriate software, analysis of each quantity for pollution and other threshold checks and lastly the implementation of a prediction model.

It is imperative for the modern society to understand the weather conditions around them as it is one of the most important tools of nature and has drastic effects on the community that evolved around it. The simple reason being that nature is relentless and it is impossible to control, however given our knowledge and innovation we can try to understand nature so that we are at least able to predict its next move and act accordingly. The theory of chaos states that even a slight ripple in our measurements may largely affect our predictive model in the future. Despite this limitation, we can assume that our techniques and predictions will result against all odds of statistics in success. This may not be a 100% true model but it is the best we can do to come close to understanding the mood swings of Mother Nature.

The main components of measurements that will be analyzed include quantities of temperature, pressure, humidity, wind, precipitation, solar irradiance and the greenhouse gas levels. These quantities will be measured by sensors which will be remotely connected to a central processing unit. Data collected from the sensors will be recorded and will be used to determine certain thresholds such as safety limits and the viability of setting up an energy harnessing plant. Data will also be logged and further processed to predict the temperature over the course of the next month. Additionally, the designed model will also try to monitor the pollution levels and raise alarms in case of a safety breach.

National Instruments will be the main contributor to the hardware and software used in this project. The main reason for our selection of NI is due to the precision, accuracy and reliability provided by the NI products. These products would include various sensors and the wireless nodes. These products provide cutting-edge technology to the project and ensure the veracity of results obtained.
THE TEAM

The following are the team members who worked on the project. Their specific tasks are listed in the table below:

<table>
<thead>
<tr>
<th>Name and University Designation</th>
<th>Designation</th>
<th>Main tasks</th>
</tr>
</thead>
</table>
| Yasser Al-Hamidi (Mechanical Laboratories Manager) | Team Captain, Manager | • Oversee Tasks  
• Maintain Correspondence |
| Khaled Hassiba (Technical Laboratory Coordinator) | Technical Assistant | • Debug and Check Controls  
• Researched on Prediction Model |
| Sami Al-Terkawi Hasib (Junior Electrical Engr. Student) | Student Member | • Sensor Connectivity  
• Node Setup |
| Bayu Juartiyono (Senior Mechanical Engr. Student) | Student Member | • Programming in LabView  
• Research on Project |
| Salman Usmani (Junior Mechanical Engr. Student) | Student Member | • Data Analysis  
• Designing Setup and Housing |
DATA ANALYSIS

In order to assess the data recorded from the measurements the following data analysis will be implemented.

Nomenclature

The abbreviations used in the report are described in the table as follows:

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>°C</td>
<td>Temperature as measured in degrees Celsius</td>
</tr>
<tr>
<td>atm</td>
<td>Atmospheric Pressure measured in atmospheres</td>
</tr>
<tr>
<td>mph</td>
<td>Wind Speed measured in miles per hour</td>
</tr>
<tr>
<td>mm</td>
<td>Amount of Rainfall measured in millimeters</td>
</tr>
<tr>
<td>Nm</td>
<td>Wavelength of Electromagnetic Waves measured in nanometers</td>
</tr>
<tr>
<td>W/m²</td>
<td>Radiation measured in Watts per meter square</td>
</tr>
<tr>
<td>ppm</td>
<td>Amount of gas measured in parts per million</td>
</tr>
</tbody>
</table>

It is imperative for the data to be understood and made sense of. The data that is recorded needs acute analysis as the whole model is dependent on the authenticity of the computed analysis. Each quantity is hereby measured and analyzed and certain thresholds are marked to raise alarms and thus mimic a real life system.

Temperature

Probably the most important quantity measured by the station is temperature. Temperature can be defined as the quantity that describes the level of hotness or coolness in the atmosphere. A thermocouple along with an equivalent resistor is used to measure the temperature. These temperature readings are used to determine and describe the quality of the weather and what can be expected. The thermocouple sensor range of measurement is:

\[-200°C < T (°C) < 350°C\]

The following ranges depict the message that will be displayed for each recording:
Table 2: Temperature Description

<table>
<thead>
<tr>
<th>Temperature Range</th>
<th>Description/Message</th>
</tr>
</thead>
<tbody>
<tr>
<td>Below 0°C</td>
<td>Below freezing point</td>
</tr>
<tr>
<td>0°C – 10°C</td>
<td>Extremely Cold</td>
</tr>
<tr>
<td>10°C – 15°C</td>
<td>Cold</td>
</tr>
<tr>
<td>15°C – 20°C</td>
<td>Mild Cold</td>
</tr>
<tr>
<td>20°C – 25°C</td>
<td>Mild Cool</td>
</tr>
<tr>
<td>25°C – 30°C</td>
<td>Mild Warm</td>
</tr>
<tr>
<td>30°C – 35°C</td>
<td>Warm</td>
</tr>
<tr>
<td>35°C – 40°C</td>
<td>Hot</td>
</tr>
<tr>
<td>40°C – 45°C</td>
<td>Very Hot</td>
</tr>
<tr>
<td>45°C above</td>
<td>Extremely Hot</td>
</tr>
</tbody>
</table>

These ranges are formed by analyzing the trends in climactic conditions throughout the globe. The Koppen system also provides a good descriptive measurement of these trends as shown in the Appendix by Figure 29. [1]

**Pressure**

Pressure is defined mathematically as the force acting per unit area or in physical terms the amount of push or pull felt by the body at a point in time. Atmospheric pressure changes are majorly attributed to the change in altitude or the change in climactic conditions. Pressure is measured at sea level and is measured by a barometer in the setup. The barometer measurement range is:

\[ 0.8 \text{ atm} < P (\text{atm}) < 1.05 \text{ atm} \]

The following ranges depict the message that will be displayed for each data recording:

Table 3: Pressure Description

<table>
<thead>
<tr>
<th>Pressure Range</th>
<th>Description/Message</th>
</tr>
</thead>
<tbody>
<tr>
<td>Below 0.9 atm</td>
<td>Low pressures (At least 30 – 50% oxygen required)</td>
</tr>
<tr>
<td>0.9 atm – 1.04 atm</td>
<td>Moderate Pressure (At least 20% oxygen required)</td>
</tr>
<tr>
<td>Above 1.05 atm</td>
<td>High Pressures (Risk of injury)</td>
</tr>
</tbody>
</table>

These values are generated by graphical analysis of “Human tolerance to pressure and atmosphere.” This study was part of a project conducted by NASA titled “Environment of Manned System.” The figure is shown in the Appendix by Figure 30. [5]
Humidity

Humidity is the measure of moistness in the atmosphere. This moistness is primarily due to the water vapors formed in the air. These vapors are measured by a relative humidity sensor. It should be noted that relative humidity differs from percentage humidity in the sense that where the latter is the percentage measurement of moisture over air, the former is the ratio of vapor pressure to the saturated vapor pressure. However, in our case for ease of analysis we would measure humidity as a percentage but keeping in mind that it is relative. The relative humidity sensor has a measuring capacity of:

$$0\% < \text{Humidity (\%)} < 95\%$$

The following table shows the displayed message at each range of measurement:

Table 4: Humidity Description

<table>
<thead>
<tr>
<th>Humidity Level</th>
<th>Description/Message</th>
</tr>
</thead>
<tbody>
<tr>
<td>Below 25%</td>
<td>Uncomfortably Dry, Danger of static shock and cracking</td>
</tr>
<tr>
<td>25% - 40%</td>
<td>Dry to Normal Conditions</td>
</tr>
<tr>
<td>40% - 60%</td>
<td>Normal to Moist Conditions</td>
</tr>
<tr>
<td>Above 60%</td>
<td>Uncomfortably Wet, Danger of corrosion and mold formation</td>
</tr>
</tbody>
</table>

Wind speed/Direction

Wind is one of the vital components of weather. The quintessential nature of wind can be judged by the fact that it has been a cause of mass destruction and loss in various parts of the world. Therefore the measurement and analysis of wind data is key to understanding the trends of Mother Nature. The wind speed and direction is measured by an anemometer and vane couple system. The direction measured by the vane is based on the angle measurement and is described in the project as follows:

Table 5: Direction Description

<table>
<thead>
<tr>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0°</td>
<td>East</td>
</tr>
<tr>
<td>1° - 89°</td>
<td>North East</td>
</tr>
<tr>
<td>90°</td>
<td>North</td>
</tr>
<tr>
<td>91°-180°</td>
<td>North West</td>
</tr>
<tr>
<td>180°</td>
<td>West</td>
</tr>
<tr>
<td>181°-269°</td>
<td>South West</td>
</tr>
<tr>
<td>270°</td>
<td>South</td>
</tr>
<tr>
<td>271°-359°</td>
<td>South East</td>
</tr>
<tr>
<td>360°</td>
<td>East</td>
</tr>
</tbody>
</table>

The anemometer used can measure up to the following range:

$$1\text{mph} < \text{Wind Speed} < 200\text{mph}$$

The following table shows the message displayed at each range of wind speed:
Table 6: Anemometer Description

<table>
<thead>
<tr>
<th>Wind Speed (mph)</th>
<th>Description/Message</th>
</tr>
</thead>
<tbody>
<tr>
<td>Below 1 mph</td>
<td>Calm</td>
</tr>
<tr>
<td>1-12 mph</td>
<td>Light/Gentle Breeze</td>
</tr>
<tr>
<td>13-24 mph</td>
<td>Moderate/Fresh Breeze</td>
</tr>
<tr>
<td>25-38 mph</td>
<td>High Wind</td>
</tr>
<tr>
<td>39-46 mph</td>
<td>Strong Wind</td>
</tr>
<tr>
<td>46-60 mph</td>
<td>High Gale, Danger of Light Destruction</td>
</tr>
<tr>
<td>60-72 mph</td>
<td>Storm, Widespread Damage</td>
</tr>
<tr>
<td>Above 72 mph</td>
<td>Hurricane, Mass Destruction</td>
</tr>
</tbody>
</table>

Wind speed is measured according Beaufort scale. The Beaufort scale is an empirical measure of the wind speeds as observed on land. [10]

Precipitation

Precipitation is the measure of rainfall or the transfer of water from the cloud cover to earth. It can be distributed into categories such as hail, freezing rain, sleet or snow. [8] A precipitation sensor/rain collector is used to measure the amount of rainfall. The measurement range for the rain collector is given as follows:

\[0 \text{ mm} < \text{Rainfall (mm)} < 1000\text{mm}\]

The following table shows the message displayed and the alarm color at each precipitation level.

Table 7: Precipitation Level Description and Alarm

<table>
<thead>
<tr>
<th>Precipitation</th>
<th>Description/Message</th>
<th>Alarm Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 – 5 mm</td>
<td>Low to High Rain</td>
<td>None</td>
</tr>
<tr>
<td>5.5 – 7.5 mm</td>
<td>High Showers</td>
<td>None</td>
</tr>
<tr>
<td>7.5 – 15 mm</td>
<td>Heavy Rain, Flooding Possible</td>
<td>Yellow</td>
</tr>
<tr>
<td>15 – 30 mm</td>
<td>Intense Rain, Threatening Flood</td>
<td>Green</td>
</tr>
<tr>
<td>Above 30 mm</td>
<td>Serious Flooding, Evacuate</td>
<td>Red</td>
</tr>
</tbody>
</table>

These measures are derived from the system implemented by the Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) [6]. They may differ from location to location depending on the altitude of the setting. However these are used as standard and can be taken to be an approximate measure of the precipitation.
Solar irradiance
Solar irradiance can be defined as the measure of sunshine that reaches earth. This electromagnetic radiation is further composed of Ultraviolet, Infra-Red and Visible Light. The solar irradiance is measured by the pyranometer. The measurement range for the solar irradiance is:

\[
370 \text{ nm} < \text{Electromagnetic Wavelength (nm)} < 1140 \text{ nm} \\
0 \text{ W/m}^2 < \text{Irradiance} < 1100 \text{ W/m}^2
\]

Solar irradiance from the sun is mostly ionizing radiation consisting of UV, infra-red and visible light. These electromagnetic waves due to their ionizing nature are harmful even at low levels. The following messages are displayed at each wavelength measurement of the radiation:

Table 8: Irradiance Description

<table>
<thead>
<tr>
<th>Wavelength (nm)</th>
<th>Description/Message</th>
</tr>
</thead>
<tbody>
<tr>
<td>Below 400 nm</td>
<td>Ultra Violet A type, Danger of Health issues on Exposure</td>
</tr>
<tr>
<td>400 – 700 nm</td>
<td>Visible Light, Safe</td>
</tr>
<tr>
<td>700 and above</td>
<td>Infra-red, Relatively non ionizing, low health risks</td>
</tr>
</tbody>
</table>

It should be noted here that solar irradiance is measured in W/m² by the pyranometer. Prolonged exposure to high amount of sunlight is also a cause of danger and may cause heat strokes or minor tissue burns. However at low irradiance levels, prolonged exposure is a source of vitamin D for the human body. [19]

Gases
One of the most important components of the project is the measure of the greenhouse gases namely Carbon Dioxide, Methane and Nitrous Oxide. These gases are measured by a specific gas sensor. The measurement range for each sensor is provided as follows:

\[
0 \text{ ppm} < \text{Carbon Dioxide (ppm)} < 500 \text{ ppm} \\
0 \text{ ppm} < \text{Methane (ppm)} < 1000000 \text{ ppm} \\
0 \text{ ppm} < \text{Nitrous Oxide (ppm)} < 1000 \text{ ppm}
\]

The following are the safety thresholds for each of the gases above which the sensor will register a safety warning and a red alarm:

Table 9: Gas Description

<table>
<thead>
<tr>
<th>Gas</th>
<th>Threshold for Maximum Exposure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon Dioxide (CO₂)</td>
<td>5000 ppm</td>
</tr>
<tr>
<td>Methane (CH₄)</td>
<td>1000 ppm</td>
</tr>
<tr>
<td>Nitrous Oxide (N₂O)</td>
<td>3 ppm</td>
</tr>
</tbody>
</table>

These gases are the main cause of pollution and are responsible for the global warming. [18] They should be acutely monitored and reported to the National Pollution Monitoring Departments.
SENSORS

The following sets of sensors are used in the project. A brief description of each is provided below:

**Anemometer**

The anemometer used is Davis Instrument’s Anemometer, as shown in Figure 1. It is used to measure both wind speed and direction. For the wind direction, the anemometer uses a free-rotating 20K ohms potentiometer. The wiper of the potentiometer is connected to the output.

![Figure 1: Anemometer](image)

One of the other lead of the potentiometer is connected to $V_{cc}$, which has the value of +5 volts, and the other lead is connected to the ground. Therefore, according to the percentage of the output voltage, the direction is determined. For example, if the output voltage, relative to the ground, is 3.5 volts, that translates to:

$$\frac{3.5}{5} \times 360 = 252^\circ$$

As for the wind speed, rotating cups are used. Each full rotation of the cups activates a switch. When the switch is activated, it connects the output to the ground, which pulls the value to ground, as show in Figure 2. This produces a negative edge, which triggers a counter to add one.

![Figure 2: Electric Circuit](image)

After adding the number pulses (negative edges), a calibration formula, included in the specification sheet of the product, is used to find the corresponding wind speed. The formula is the following[11]:

$$\frac{2.25 \times N_{pulse}}{T_{seconds}} = \text{Speed in mph}$$
Rain Collector

The rain collector used is also from Davis Instruments, as shown in Figure 3. Similar to the anemometer, the rain collector hosts a tilting spoon, which when is filled with 0.2 mm of water, activates a switch and discards the water. When the switch is activated, DIO will be pulled to ground to create a pulse and trigger the count, the same way the anemometer does. [12]

Humidity

The relative humidity sensor used is from Vernier, as shown in Figure 4. All of the Vernier sensors used in this project give a linearized output between ground and +5 V. They are also easily interfaced and connected to circuit using a proprietary adapter.

Each sensor’s manual comes with calibration data that would translate the output voltage to usable data values. The sensor can read the values of the relative humidity from 0 to 95% (± 5%). [13]

Barometer

Similar to the humidity sensor, the barometer used for this project is also from Vernier, as shown in Figure 5. The sensor has the range of 0.8 to 1.05 atm. [14]

Pyranometer

Similar to the humidity sensor, the pyranometer used for this project is also from Vernier, as shown in Figure 6. The pyranometer is used to measure solar irradiance. It is sensitive to light spectrum where 90% of the solar energy is concentrated. It would be used to calculate the efficiency of solar cells, and the feasibility of using solar cells in certain regions of the world, as it reads the available solar power in W/m². The pyranometer has the range of 0 to 1100 W/m². [15]
Thermocouple

The thermocouples used are T type thermocouples.

**CO₂ and CH₄ Sensors:**

As for CO₂ and CH₄ measurement, the corresponding gas sensors were purchased from Dynament, as shown in Figure 7. Both have the same form factor, with linearized output ranging from 0.4 V for 0% volume of gas, up to 5 V for 100% volume of gas. [16]

**N₂O Sensor:**

Similar to the CO₂ and CH₄ sensors, the N₂O sensor is also from Dynament. This sensor can only measure N₂O values of 0 to 1000 ppm, or 0 to 100% volume of N₂O. Also, a special kit is used with the sensor to give a linearized output of readings. [16]
The WSN-3212 and WSN-3202 are intelligent wireless nodes that can be programmed to add extra features to the project. Using the WSN Pioneer Module, a ready-made template was available, which simplified the node VI construction for this project. Also, with the help of the available online resources, a template that would also count digital events was found, and modified a little. [17]

Figure 8 shows the initialization of the VI. When the node starts, the case structure goes to the “Start” case, where the counter it reset to 0, and the sample interval is set to the default value of 60 seconds. The sample can be changed through the host VI, which will be demonstrated.

The default value was set to 60 seconds, so that the node can conserve more energy. With a sample interval of 60 seconds, and therefore, transmission interval of 60 seconds, the node could run up to 36 months, according to the benchmarking of the nodes. When DIO detects a negative edge, it triggers the case structure to go the “DIO Notification” case, as shown in Figure 9.
In this case, all that would happen is the value of Freq Count will be incremented by 1. When sample interval is up, the “Sample” case is invoked, as shown in **Figure 10**.

The outputs of the node were renamed according to their functionality to make it easier and less confusing when constructing the host VI.
Figure 11: When the host receives a message from the VI

Figure 11 shows the case when the node receives a message from the host VI. In this case, the host VI can either redefine the value of the counter, by sending the message “CTR: XX”, where XX is the new value of the counter, or change the sample interval by sending “PER: XX”, where XX is the new sample interval in seconds, as shown in Figure 12.

Figure 12: With the new sample interval
Lastly, in case the network status changes, the node sends a message to confirm whether it was connected or not, as shown in Figure 13.

![Figure 13: Message for connection](image)

To make the construction of the host VI even less confusing, sub VI containing the calibration data of each sensor to be connected is created, for which an example is shown in Figure 14.

![Figure 14: Sub VI for calibration](image)
CIRCUIT CONNECTION AND POWER

Figure 15 is the block diagram that explains the connections of the nodes, sensors, gateway, and the host PC.

Figure 15: Connection Diagram

Figure 16 and 17 show actual picture of the connections. It should be noted that these connection are temporary are just for prototyping and getting sample data. Similar connection will be made when the whole circuitry is transferred onto the weather station.
The sensors require more power than the nodes can deliver through the DIO power port. Therefore, a separate battery pack connected to a boost/buck converter is used to provide the +5 V as $V_{cc}$. 

Figure 156: Actual Connections 1

Figure 167: Actual Connections 2
USER INTERFACE

The user interface uses a tabbed function to reduce clutter on the front panel. The tabs are separated by different objectives. The tabbed user interface is shown in Figure 18-21.

- **User Input Tab** - The user input tab is mainly used for the user to enter the limits of each weather property. This in collaboration with the warning system will inform the user if there is an abnormality in the weather. The user input tab consists of all the gas thresholds that is considered to be safe or acceptable. It also contains the maximum temperature, wind speed humidity and radiation.

- **Temperature Tab** - The temperature tab reads the obtained temperature data from the thermocouple and displays it in the user interface. It consists of a thermometer, numerical and graph indicator to show the change of temperature over a period of time.
- Wind tab - the wind tab displays the wind data obtained from the anemometer. Two kinds of data are shown here, the wind speed and the wind direction in terms of the compass direction.

![Wind tab](image)

**Figure 20: Wind tab**

- Air quality tab - the air quality tab displays the four measured gas composition in the air, CO$_2$, CH$_4$, N$_2$O and SO$_2$. A meter displays how critical the composition of the gas is. Implying the red has surpassed the limit. A chart that shows the change of composition is also shown in the tab.

![Air Quality tab](image)

**Figure 21: Air Quality tab**
WARNING SYSTEM

A warning system was also implemented into the VI. The warning system gives a warning text if the obtained value exceeds the limit of the weather property. As mentioned before, the limits are entered by the user from the front panel. The warning messages are also logged into a text file for later reference. Independent warning messages are linked to each of the sensors. A screen shot of the warning system is shown in Figure 22.

![Figure 22: Warning indicator](image)

The warning system consists of a subsystem to generate text for each of the sensors. After the comparison is made from the data obtained and the limit entered, the case structure is used to select which path the system should progress on. If the comparison is true (value obtained is larger than limit), the system proceeds with case to generate the warning message by the use of the build text function connected to every comparison output. If the value obtained is less than the limit value, the false case will proceed and an empty string will be generated.

![Figure 23: Warning generator Sub VI](image)
POWER AND SPACE SAVING FUNCTIONS

Time stamping is enabled in every sensor node to provide a time and date reference. This will be used later with the use of regular expression if the user requires data at a specific date, they could search it easily.

One important function implemented into the VI is the use of shared variable. The code shown in Figure 24 operates to check if the data obtained from the sensor is the same data acquired previously. If the current and previous data are similar, the data will not be logged into the file. However if the data is different the data will be written into the log file. This is done to reduce redundant data logged into the file therefore reducing the space consumption of the file.

In order to see how fast the system really is a benchmarking system is implemented into the loop. A tick counter is used in the outside and internal loop. The counter is connected to a shift register and is then subtracted from the outer loop counter. The difference in the count is the time difference. The important property here is that to optimize the speed of the VI to save power consumption. If the system is retrieving data faster than the weather changes, the efficiency decreases. So the user can reduce the rate at which the system obtains data.

Two types of logging are used in the code, the first is write to measurement file and the other is write to text file. The former is to log values obtained from the sensors including the time stamps of each value whereas the latter logs the warnings that generated during the operation.
WEATHER STATION SETUP

The weather station was built by scrap material that was scavenged from the university machine shop and was further altered to build the major shafts holding the weather station. The main components of the system include the following:

**Electrical Insulation Box**
The electrical insulation box was used to place all the wireless nodes inside and acted as insulation towards outside conditions. The box contained the breadboard, all the wiring circuits and wire openings through which the node antennas, wires and thermocouple were passed. The picture below shows the arrangement of the complete wiring. As can be seen, the box has attached components on either half. One half of the box holds the nodes that are taped on the side and are easily removable in case a change of battery is required and the other half of the box holds the breadboard with all connections. The diagram is shown below:

![Figure 25: Electric Circuit (Left) and WSN with Antennas Protruding from the Bottom (Right).](image)

**The Sensor Housing**
The sensor housing was a projected method of housing the sensors in an enclosed umbrella like structure that would protect the sensors from direct rain or snow. However the housing would still have openings so that the ambient temperature is perfectly recorded by the sensors. The modeling of the structure was performed on Solidworks. Plastic was used as the material of choice for its construction owing to low cost and susceptibility to rust.

As can be seen from the figure the umbrella like structure would help the rain or snow to slide down. There are openings from the sides for recording of the ambient temperature and also to pass the wiring through. The top of the box is open since this is a part drawing. In the complete assembly the top would be covered by the lid. The design of the housing is shown below in 3 different views:
Tripod and Aluminum Bar Members
The whole station was set on a camera tripod stand. An aluminum bar of roughly 1.5 meter height was machined to vertically pass through the central shaft of the tripod. In order to prevent any vibrations in the system a piece of plastic was inserted in between the through shaft and the holding aluminum bar in order to damp the effects of any vibrations. The top of the aluminum bar was attached to a mild steel bar horizontally with holes to hold any component.

The Complete Design
The complete design of the whole setup is shown below. Due to the implementation of an adjustable tripod the tripod can be used at 3 different heights. All the components except the sensor housing are attached as seen. The housing was not manufactured due to time constraints. Further pictures of the design and setup are shown in the appendix. The setup at different heights is shown below:
Figure 28: Setup at a height of 176 cm

Figure 29: Setup at a height of 218 cm (max)
IMPORTANCE OF PREDICTION MODEL FOR A WEATHER STATION

Weather prediction or forecasting is of extreme significance in many applications. Information obtained from forecasting is used for decision-making for a wide range of activities. These activities can vary from something significant, such as launching a satellite into an orbit, to something ordinary like planning a picnic over the weekend.

Unfortunately, weather forecasting is generally very complex and the associated mathematical models require a lot of data and huge amounts of computing power. Another attribute of its complexity can be seen by the fact that the predicted parameter is more likely to be dependent on other parameters. For example, wind speed tends to be highly proportional to atmospheric pressure, and pressure is a function of temperature. Because of that, simplified models are often proposed. The team proposes the following prediction model.

In this model, we require hourly meteorological data of the previous year. The proposed model assumes that the predicted parameter is independent of other meteorological parameters and it is as follows:

- Calculate the average for a given period of this year, up to the day of interest.
- Calculate the average and standard deviation of the previous year for a similar given period.
- Assuming that the standard deviation would be the same across different years, the predicted range will have a probability curve with the average of this year and the standard deviation of last year. This final value of the range will depend on the end-user’s choice of the level of confidence, i.e., 90, 95 or 99%.
FUTURE PROSPECTS

The project is merely a precursor to the future prospects of our work. The assistance provided by National Instruments has improved the performance of our project tenfold with better, faster and more accurate results. The project can be honed in several different ways and various considerations can be made for the project. The prediction model as discussed can be made more precise by the implementation of probability distribution curves. Different models were proposed for the project however one was selected as discussed. This model is based on regression and takes outliers into account. However with an increased data set or sample number these outliers can be neglected.

Moreover, the team is also looking forward to make certain enhancements on the project. Some of these would include using sensors to calculate the amount of precipitation in the soil and then on the basis of that data collected regulating an irrigation plant. The design of the weather station can also be improved by enacting a stress analysis for the whole structure and testing it for different conditions. Similarly, implementation of solar cells can also be a potential option for power generation as opposed to the battery system that is now in place. Gas sensors can be increased to account for more than just the greenhouse gases and a complete pollution monitoring study can be evaluated. This project is a great initiation of the team’s work and will be continued after the competition.
REFERENCES


Figure 30: Koppen Climate System

Figure 31: Human Tolerance to Pressure
Figure 32: Setup depicting anemometer, electric box, pyranometer and the rain collector

Figure 33: The back view of the setup showing the rain collector