INTELLIGENT STREET LIGHTING SYSTEM

PRODUCT DESIGN PRACTICE (INT303)

Documentation

--B2 28--

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Industry Domain
Consumer Electronics

Problem Statement

Reduction of power consumption and increased energy efficiency in street lights.

Street Lights form an important part of urban infrastructure and are crucial especially during the night. Human control over lights leads to leaving lights on for long durations without any use. Street lights consume huge amounts of energy and they are an unavoidable burden on municipal budgets too. India Spends around 12 crore rupees just on street-lighting per day. Additionally, the importance of clean energy is emphasized by the very sustainable development goals of United Nations and it is high time we optimize the usage of energy.

Solution

An adaptive lighting technology which comes as an attachment to any existing lighting system, facilitating various modes of operation as follows:

1. A low-power mode which is configured when no presence is detected around the light.
2. A high-power mode which is turned on when a requirement for light is detected.
3. An intermediate mode where intensity of light varies based on external light intensity.

Monitoring of energy consumption and feedback of system functioning can be regularly obtained. Malfunction if any in the system can also be notified.

References

https://www.analyticsindiamag.com/smart-cities-optimize-street-lighting-india/
https://www.mapsofindia.com/my-india/government/street-lighting-in-india-and-need-for-energy-efficient-solutions
https://quality-one.com/qfd/
http://www.chennaicorporation.gov.in/departments/electrical/

<u>**Week 1**</u>

Progress

The problem statement was identified, and a prospective solution was proposed. A tentative project plan was devised to achieve the target.

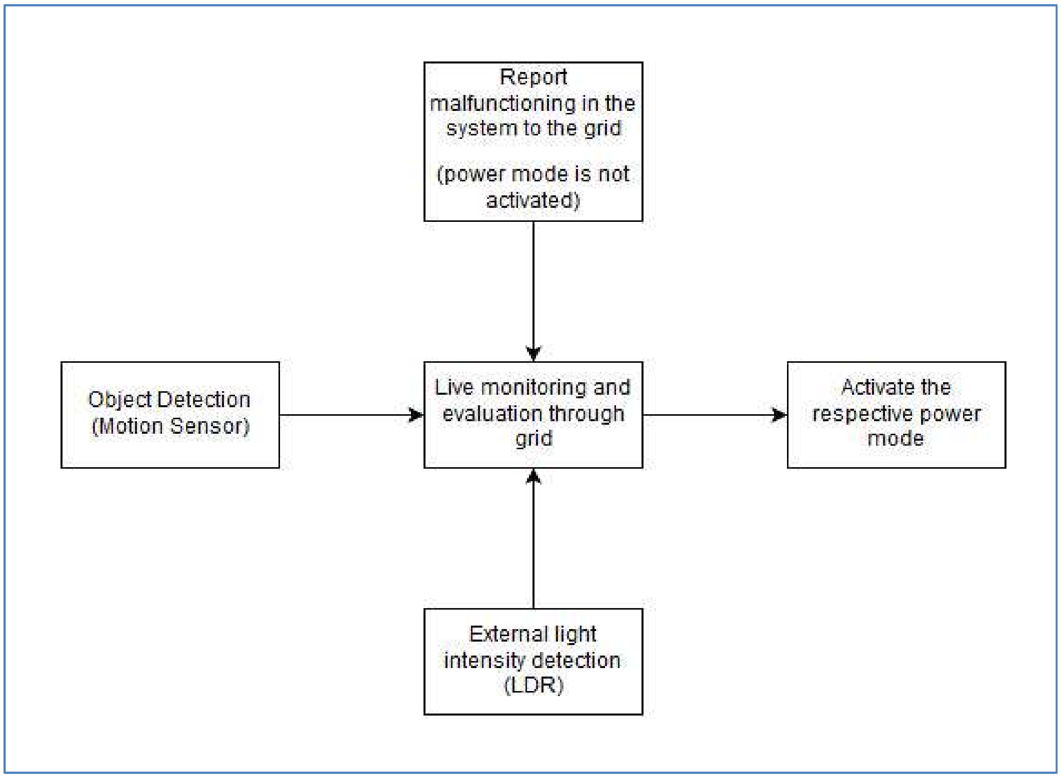


Figure 1: Flow chart depicting functioning of model

Background Research

Street lighting is a particularly critical concern for public authorities in developing countries because of its strategic importance for economic and social stability. Inefficient lighting wastes significant financial resources each year, and poor lighting creates unsafe conditions. A well-designed, energy-efficient street lighting system should permit users to travel at night with good visibility, in safety and comfort, while reducing energy use and costs and enhancing the appearance of the neighbourhood. Conversely, poorly designed lighting systems can lead to poor visibility or light pollution, or both. Quite often, street lighting is poorly designed and inadequately maintained (e.g., there are large numbers of burned-out lamps), and uses obsolete lighting technology— thus consuming large amounts of energy and financial resources, while often failing to provide high- quality lighting. Aims to remove the imbalance in availability of light and hopes to provide clean alternate energy to all and optimize energy usage.

Tentative Project Plan

Week 1:

- Identification of problem statement.
- Formulation of project plan and BoM list.

Week 2:

- Refine problem statement and gather additional resources to support our solution and finalize it.
- Begin component collection and purchase of materials required.

Week 3:

- Complete component collection and purchase of materials.
- Discussion of issues with project mentor and lab technicians.

Week 4, 5:

- Testing of components purchased to ensure proper functioning.
- Coding of Arduino for integrating LED operation with functioning of LDR (external light intensity) and PIR (motion) sensors.

Week 6:

- Break for Quiz 1, Inter-IIIT sports meet.
- Faculty review of progress

Week 7, 8:

- Building and testing of circuit - hardware implementation of solution.

Week 9:

- Integrating hardware with application (software).

Week 10:

- Break for Quiz 2.

Week 11:

- Testing of the entire model for faults and failure
- Fine-tuning sensor calibration according to use case for accuracy.

Week 12:

- Testing and implementing energy efficiency and optimization techniques.

Week 13:

- Demonstration of the working prototype.

Bill of Materials (BoM)

Material Name	Cost Per Piece (in ₹)	Quantity (in Nos.)	Total Cost for the material (in ₹)
Arduino UNO	415.25	4	1661
Arduino Cable	50.85	2	101.70
PIR Sensor	127.12	5	635.60
LDR Sensor	4.24	10	42.40
Ultrasonic Sensor	80	8	640
Wifi Module (ESP8266)	194.92	4	779.68
LED	2	60	120
Jumper Wires -M2M	5.93	50	296.5
Jumper Wires -M2F	5.08	50	254
Bread Board		2	
Connecting Wires		20 meters	
Battery(9V)	13	10	130
Battery Snapper (9V)	5	5	25
Battery(12V)		1	
Miscellaneous Requirements			250
CGST (18%)			680.32
Total = ₹4935.88			

Division of workload

Task	Team Members
Setting up and downloading Arduino IDE	Abirami
Testing of Arduino, LED, Wifi-module, LDR and PIR sensors	Vinitha
	Harshitha
Testing of jumper wires for continuity	Sri Chand
	Shukrithi
	Anush
Calibration of LDR to detect different light intensities	Shukrithi
	Abirami
Calibration of PIR to detect range of movements.	Harshitha
	Sri Chand
Setting up LDR circuit	Vinitha
Setting up PIR circuit	Anush
	Sri Chand
Connecting the LED Network to the appropriate sensors and testing functionality.	Abirami
	Vinitha
Arduino coding of LDR	Harshitha
	Shukrithi
Arduino coding for PIR	Anush
	Vinitha
Integration of LDR and PIR circuits	Abirami
	Sri Chand
Consolidation of programs to enable integration of modules	Anush
	Harshitha

Note: At the beginning of each week, testing of system (electrical testing of circuit and test case of software) built so far is done before the task for the next week commences.

Week 2

Progress

Problem statement was fine-tuned to focus on energy efficiency and reduction of power consumption. Proposed model was optimized for energy efficiency.
Based on ethnographic studies performed in the previous semesters, a proper set of use case that is to be implemented in the prototype was defined.

Components and materials procured:

- Battery
- Arduino UNO and Cable
- Assorted Wires
- LDR Sensors

Items left:

- Jumper Wires
- Breadboard
- PIR Sensor
- Wifi – Module
- Miscellaneous

Use Case: Two lane two-way road

Justification for two-way use case:

Any roadway can be reduced to a two-lane two-way road for the purpose of traffic monitoring and thereby virtual street light network simulation. This solution was arrived at after trying to optimize complex roadways like main roads in cities, four-way junctions, highways, etc.

Network of streetlights vs stand-alone

Network enables:

1. Resource optimization and information sharing.
2. Efficient troubleshooting.
3. Feedback and feed-forward systems.

Therefore, higher priority was given to network-based simulation vs standalone simulation and it was decided that our prototype would reflect the same.

Faculty review

- Focus was on practical implementation of feedback system.

Week 3

Progress

Components purchased:

- Wifi – Module
- Breadboard
- Jumper Wires

Items left:

- PIR Sensors
- Miscellaneous

Logic implementation

External light intensity is sufficient (A)	Motion Detected (B)	Operation case
0	0	OFF
0	1	ON (Intensity depends on external light intensity)
1	0	OFF
1	1	OFF

1→ Sufficient light intensity/motion detected
0→ Light intensity not sufficient/motion not detected

- Logic to be implemented = A'B
- Sensor to detect light intensity→ LDR
- Sensor to detect motion→ PIR
- Logic to be implemented using NOT and AND gate.
- Output of LDR is not be given as input to NOT gate.
- Output from NOT gate and PIR are to be given as input for AND gate.
- Output from AND gate is to be given to microcontroller thereby pushing logic from software to hardware. This increases speed of operation of system.

Faculty Review

- Proposed solution needs to focus on minimizing overall delay in network response.

Week 4

Progress

- Overall delay in network can be divided into two -
  1. Delay in response of the individual light based on data
  2. Delay in propagation of information throughout the network. (from one light to the neighboring one)
- Minimizing delay 1:
  1. Reducing inductance in the overall lighting system.
  2. Removing residual capacitance and resistances increases speed of operation of system.
- Minimizing delay 2:

  Requirements:

  In order to decrease this, information should travel at a speed faster than the speed of approaching vehicle.

  Speed of approaching vehicle:

  - Consider a linear network of lights.
  - Input speed for light n will be based on difference between sensing time of lights n-1 and n-2.
  - Basically, speed of approaching vehicle can be calculated based on difference in sensing times of any two consecutive lights.
  - This delay also depends on data communication rate through the processors and network topologies. Reducing communication at the physical level and shifting to wireless communication will help reduce delay. For this, we propose VLC (visible light communication) which is to be implemented after the basic system is complete.

Faculty Review

- Optimize software performance.
- Improve modularity.

Week 5

Progress

- Completed purchase of components.
- Focus was on optimizing software performance through better coding practices.
- Integration of PIR and LDR sensors with Arduino. (connections and coding)

References

https://maker.pro/arduino/tutorial/how-to-use-an-ldr-sensor-with-arduino
https://www.instructables.com/id/Introduction-to-PIR-Sensor-and-Integrating-It-With/

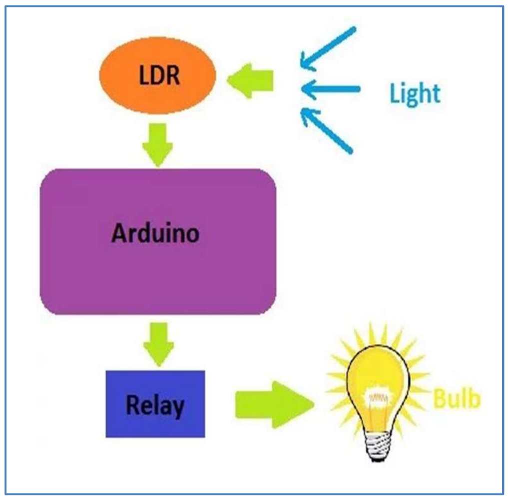


Figure 2: Arduino functioning

Faculty review

- Focus was on the practical difficulty and problems that might arise during implementation.

<u>**Hackathon 1**</u>

Features demonstrated

- Reactive level of intelligence.
- Street light intensity variation based on:
  - Motion of vehicles / humans / animals (PIR sensors).
    - The intensities of contiguous LEDs will vary accordingly as the object approaches and moves on.
  - External light intensity (LDR sensors)
    - During daytime, LDR will detect maximum light due to presence of sunlight and LEDs will not glow.
    - During night time, LDR will detect minimum light and the LEDs will glow.
    - For intermediate light detected by LDR, the LEDs will glow at varied intensities.
- The range of light detected by LDR is divided into 5 categories:
  - ➢ 0-249
  - ➢ 250-499
  - ➢ 500-749
  - ➢ 730-999
  - ➢ 1000-1023
- Sensors were calibrated for optimal performance. Range of LDR sensor is (0-1023). Range of PIR sensor is 7-12 metres.
- Design was implemented for a series of three LEDs separately for LDR sensor and PIR sensor.

Division of Workload

Task	**Team Members**
Individual components testing (PIR sensor, LDR sensor, jumper wires, LEDs)	Abirami Anush
Hardware connections and Debugging (LDR sensor and PIR sensor with the LEDs	Sri Chand Harshitha
Downloading Arduino IDE and Arduino Coding (PIR sensor and LDR sensor)	Vinitha Shukrithi

Codes

streetlighting

```
int analogpin=A3;
void setup()
{
  Serial.begin(9600);
  pinMode(5,OUTPUT);
}
void loop()
{
  int val;
  val=analogRead(analogpin);
  Serial.println(val);
  if(val>=0 && val<=249)
  analogWrite(5,255);
  else if(val>=250 && val<=499)
  analogWrite(5,192);
  else if(val>=500 && val<=749)
  analogWrite(5,128);
  else if(val>=750 && val<=999)
  analogWrite(5,64);
  else
  analogWrite(5,0);
}
```

network

```
int analogpin=A3;
void setup()
{
  Serial.begin(9600);
  pinMode(5,OUTPUT);
}
void loop()
{
  int val;
  val=analogRead(analogpin);
  Serial.println(val);
  if(val>=0 && val<=249)
   {
  analogWrite(3,255);
  analogWrite(5,255);
  analogWrite(6,255);
}
  else if(val>=250 && val<=499)
   {
  analogWrite(3,192);
  analogWrite(5,192);
  analogWrite(6,192);
```

```
}
  else if(val>=500 && val<=749)
   {
  analogWrite(3,128);
  analogWrite(5,128);
  analogWrite(6,128);
}
  else if(val>=750 && val<=999)
 {
  analogWrite(3,64);
  analogWrite(5,64);
  analogWrite(6,64);
}
  else
 {
  analogWrite(3,0);
  analogWrite(5,0);
  analogWrite(6,0);
}
}
```

Lessons learnt

- Use different colored wires for positive and negative terminals of the sensors to save time and confusion. (Color Coding)
- Mechanical design implementation is not as easy as it looks. Needs to be improved and should be more stable.
- Test if all the individual components are working before starting to assemble them.
- Make sure that the Arduino coded pins match with the respective Arduino pins given hardware connections. We wasted plenty of time trying to resolve this problem while doing the hardware connections for PIR sensor. We nearly arrived at a conclusion that the component was faulty.
- Always have insulation tape handy to prevent short circuits and make sure that there are no loose connections in the circuits.
- Have backup for all the cheap components in case of failure.
- PIR: Factors that affect measurements
    - Temperature Sensitivity - In warmer weather, objects in the field of view of a PIR will tend to be warmer, and the temperature difference between them and human skin will diminish. This can degrade the performance of a PIR.

    - Detector Window Vulnerability - The silicon window on a detector is vulnerable to dirt or grease. Avoid touching the component if it is not protected by lenses.

New insights

- Use of truth tables and logic gates to implement the design effectively and in an optimized manner in the network.
- Adapt the product to be fixed on a network of street lights.

Next steps

- Create a database in MySQL to get continuous feedback from the network. Feedback is necessary to identify the components which are not working in a streetlight in any area.
- Integration of the LDR and PIR sensors. Light intensity will be influenced by both external lighting and motion of vehicles or humans.
- Reduce the delay in the system.
- Improvised mechanical design for stability and feasibility.
- Implementation of final prototype of the proposed solution.

Video Link

https://drive.google.com/open?id=1QqxKApMJ7lEIKby_piwWByn0Of61EhlA

Week 6

Progress

- Documentation for hackathon 1.
- Hardware and software integration of LDR and PIR sensors.
- For this purpose, a new code was written with 16 different use cases.
- Started working on feedback database.

Faculty Review

- In order to increase quality and workflow efficiency, we were asked to focus on a few key aspects of prototype instead of diversifying it.

Thus, database for network feedback has been given lower priority.

Week 7

Progress

- System was made robust by realizing a mesh topology between sensors from three adjacent streetlights and providing the input to one streetlight.
- This way, we not only eliminate single point of failure but also improve fault (values) tolerance.
- Integrated the sensor system with actual street lights by understanding implementation failures.

Faculty Review

- Try to come up with a new form design for the existing street light structure in order to improve efficiency.

Week 8

Progress

Update and implementation of form design

- The various form designs discussed were as follows:

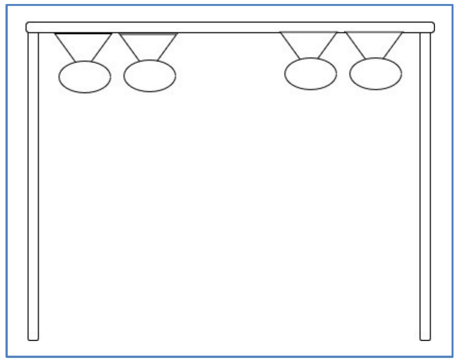


Figure 3: Form Design 1

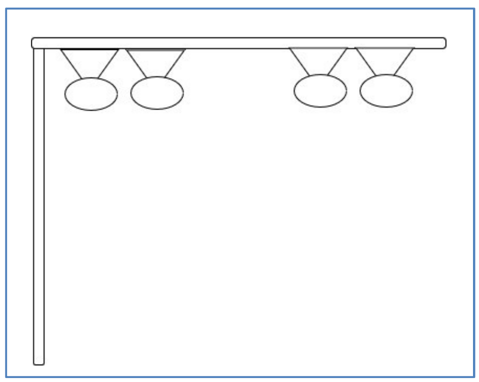


Figure 4: Form Design 2

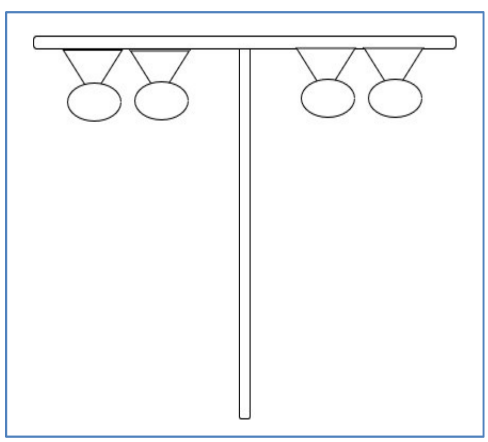


Figure 5: Form Design 3

- In all of the above cases, placing horizontal beams across the width of the road or highway, a major parameter that comes into play is the height at which the beams are placed.
- The constraints for height are as follows:
    - Height of lamp ∝ 1/intensity
    - Height must be > max height of passing heavy weight vehicles such as trucks, lorries, goods carriers and shipment vehicles.
    - The height of the lamp also determines the area of coverage.

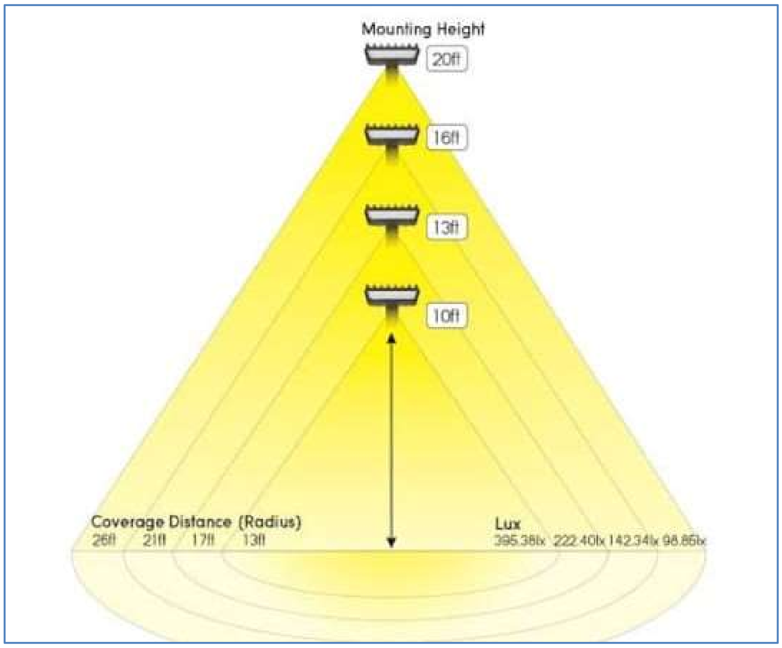


Figure 6: Variation of area of coverage with height

Disadvantages of proposed designs

- During maintenance the entire road needs to be closed as the cars and trucks will be passing directly below the maintenance workers and this compromises their safety in case they slip.
- Cost of a horizontal beam is more than the cost of 4 individual vertical beams.
- Due to the above constraints, the three designs involving horizontal beams were discarded.

Angle of inclination

- The other parameter that plays a role in the design is the angle of inclination between the lamp and its supporting pole.
- Angle of inclination determines:
    - Area of coverage of the lamp.

- After considering test cases in which the angle was varied from an acute angle -> 90 degrees -> an obtuse angle, and considering their corresponding areas of coverage, it was concluded that a 90degree angle would be optimum for area of coverage and efficiency.

Conclusion:

- The existing physical form with changes in the height and with the angle of inclination at 90 degrees would be the most efficient design that can be implemented in our prototype.

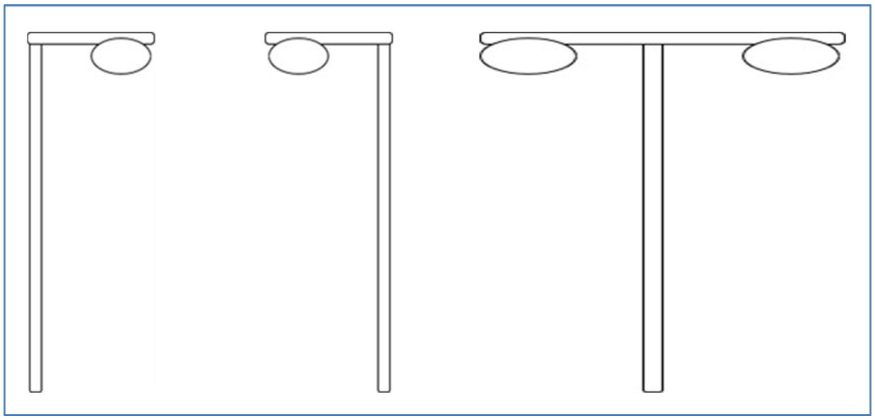


Figure 7: Current Design of street light.

Faculty Review

- Focus was on optimization methods to improve accuracy and efficiency of model

<u>**Week 9**</u>

Progress

Energy efficiency and Optimization

- As our product focuses on achieving the sustainable development goals of United Nations, methods to further decrease energy consumption and increase efficiency were considered.
- Introduction of piezoelectric sensor in place of existing PIR sensor in the product was discussed.
- A piezoelectric sensor uses the piezoelectric effect to measure changes in acceleration, strain, or force by converting the physical change to an electrical change.
- In addition to detecting vibrations, these types of sensors are used for detecting mechanical shock.

Piezoelectric Advantages:

1. Greater energy efficiency when compared to PIR sensors.
2. Piezoelectric sensors can be calibrated more accurately, thereby increasing the precision and frequency of the output obtained.

Challenges of implementing Piezoelectric sensor:

1. Very expensive, especially in comparison to sensor currently in use.

Strategy for positioning and placement of sensors for our road conditions was not optimal.

- The trade-off between energy efficiency and accuracy with cost and implementation was not practical and hence deploying piezoelectric sensors was not considered.

Week 10

Progress

Monitoring Energy efficiency:

- By increasing availability of external light conditionally, energy consumed by the light is decreased.
- Use of reflective (glow in the dark) kind of material as an outer coating for the structures will help increase energy efficiency on highways and other cases where there is a heavy traffic with usage of high-power beams in the headlights at night.
- In order to monitor energy efficiency, power consumed by the light is calculated as a function of the output given by the LDR and PIR sensors.
- The values obtained in this manner is compared with existing real-life power consumption data obtained from the existing street lights and thus energy efficiency is shown.

Case y1: (lowest level of intensity detected by LDR)

	Sensor 1	Sensor 1&2	Sensor 2&3	Sensor 3&4	Sensor 4
LED 1	255	128	0	0	0
LED 2	128	255	128	0	0
LED 3	64	128	255	128	0
LED 4	0	64	128	255	255

For each case the LEDs will be switched on for 0.5 s.

Let $x \rightarrow$ ~~energy~~ Power

Sensor 1: $\left(\frac{255}{255} + \frac{128}{255} + \frac{64}{255} + \frac{0}{255}\right) \times 0.5x$

$= 1.75 \times 0.5x$

$= 0.875x$

Sensors 1 & 2 : $\left(\frac{128}{255} + \frac{255}{255} + \frac{128}{255} + \frac{64}{255}\right) x \times 0.5$

$= 2.25 \times 0.5x$

$= 1.125x$

Sensors 2 & 3 : $\left(\frac{0}{255} + \frac{128}{255} + \frac{255}{255} + \frac{128}{255}\right) x \times 0.5$

$= 2 \times 0.5x$

$= 1.0x$

Sensors 3 & 4 : $\left(\frac{0}{255} + \frac{0}{255} + \frac{128}{255} + \frac{255}{255}\right) x \times 0.5$

$= 1.5 \times 0.5x$

$= 0.75x$

Sensor 4 : $\left(\frac{0}{255} + \frac{0}{255} + \frac{0}{255} + \frac{255}{255}\right) x \times 0.5$

$= 1 \times 0.5x = 0.5x$

Total energy = $\boxed{4.25x}$

Case y2:

	Sensor 1	Sensors 1 & 2	Sensors 2 & 3	Sensors 3 & 4	Sensor 4
LED1	192	96	0	0	0
LED2	96	192	96	0	0
LED3	32	96	192	96	0
LED4	0	32	96	192	192

For each case the LEDS will be switched on for 0.5s.

Let $x \rightarrow$ Power

Sensor 1: $\left(\frac{192}{255} + \frac{96}{255} + \frac{32}{255} + \frac{0}{255}\right) x \times 0.5$

$= (0.75 + 0.375 + 0.125 + 0) x \times 0.5$

$= 0.625x$

Sensors 1&2: $\left(\frac{96}{255} + \frac{192}{255} + \frac{96}{255} + \frac{32}{255}\right) x \times 0.5$

$= 0.8125x$

Sensors 2&3: $\left(\frac{0}{255} + \frac{96}{255} + \frac{192}{255} + \frac{96}{255}\right) x \times 0.5$

$= 0.75x$

Sensors 3&4: $\left(\frac{0}{255} + \frac{0}{255} + \frac{96}{255} + \frac{192}{255}\right) x \times 0.5$

$= 0.5625x$

Sensor 4: $\left(\frac{0}{255} + \frac{0}{255} + \frac{0}{255} + \frac{192}{255}\right) x \times 0.5$

$= 0.375x$

Total Energy $= \boxed{3.125x}$

Case y3:

	Sensor 1	Sensors 1&2	Sensors 2&3	Sensors 3&4	Sensor 4
LED 1	128	64	0	0	0
LED 2	64	128	64	0	0
LED 3	16	64	128	64	0
LED 4	0	16	64	128	128

For each case the LEDs will be switched on for 0.5s.

Let $x \rightarrow$ Power

Sensor 1: $\left(\frac{128}{255} + \frac{64}{255} + \frac{16}{255} + \frac{0}{255}\right) x \times 0.5$

$= (0.5 + 0.25 + 0.0625 + 0)x \times 0.5$

$= 0.8125 \times 0.5x = 0.40625$

Sensors 1&2: $\left(\frac{64}{255} + \frac{128}{255} + \frac{64}{255} + \frac{16}{255}\right) x \times 0.5$

$= 0.53125x$

Sensors 2&3: $\left(\frac{0}{255} + \frac{64}{255} + \frac{128}{255} + \frac{64}{255}\right) x \times 0.5$

$= 0.5x$

Sensors 3&4: $\left(\frac{0}{255} + \frac{0}{255} + \frac{64}{255} + \frac{128}{255}\right) x \times 0.5$

$= 0.375x$

Sensor 4: $\left(\frac{0}{255} + \frac{0}{255} + \frac{0}{255} + \frac{128}{255}\right) x \times 0.5$

$= 0.25x$

Total Energy = $\boxed{2.0625x}$

Case y4:

	Sensor 1	Sensors 1&2	Sensors 2&3	Sensors 3&4	Sensor 4
LED1	96	48	0	0	0
LED2	48	96	48	0	0
LED3	16	48	96	48	0
LED4	0	16	48	96	96

For each case the LEDs will be switched on for 0.5 s.

Let $x \rightarrow$ Power

Sensor 1: $\left(\frac{96}{255} + \frac{48}{255} + \frac{16}{255} + \frac{0}{255}\right) x \times 0.5$

$= 0.625x \times 0.5$

$= 0.3125x$

Sensors 1&2: $\left(\frac{48}{255} + \frac{96}{255} + \frac{48}{255} + \frac{16}{255}\right) x \times 0.5$

$= 0.40625x$

Sensors 2&3: $\left(\frac{0}{255} + \frac{48}{255} + \frac{96}{255} + \frac{48}{255}\right) x \times 0.5$

$= 0.375x$

Sensors 3&4: $\left(\frac{0}{255} + \frac{0}{255} + \frac{48}{255} + \frac{96}{255}\right) x \times 0.5$

$= 0.28125x$

Sensor 4: $\left(\frac{0}{255} + \frac{0}{255} + \frac{0}{255} + \frac{96}{255}\right) x \times 0.5$

$= 0.1875x$

Total energy = $\boxed{1.5625x}$

Case y5: (highest level of light intensity detected by LDR)

i.e Daytime – All streetlights will remain OFF.

$\Rightarrow$ No energy = $\boxed{0x}$

Ethnography case considered 3 hrs for each case (y_1, y_2, y_3, y_4, y_5)

3 hrs $\rightarrow$ 180 mins

180 mins $\rightarrow$ 10800 seconds

For 1 case to complete 2.5 seconds.

$$\frac{10800}{2.5} = 4320 \text{ cases}$$

Total time of ethnography = 15 hrs (3 hrs × 5 cases)

4320 cases × 5 = 21600 cases.

For each case, energy consumed is $20x$ ~~without~~ in original system.

$$\Rightarrow 21600 \times 20x = \boxed{432000x}$$

Total energy consumed in our Intelligent Street Lighting system for given ethnography study

$$= 4.25x + 3.125x + 2.0625x + 1.5625x + 0x$$

~~= 11x Substitute x,~~

Final calculations from excel sheet, for one lane

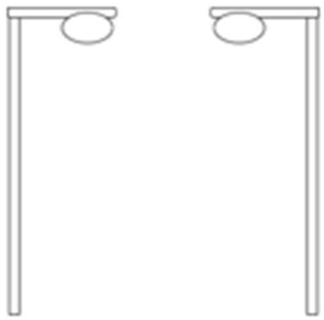
$$= 4785.813x$$

Thus, for 4 lanes $\Rightarrow$ $4785.813x \times 4 = 19143.252x$

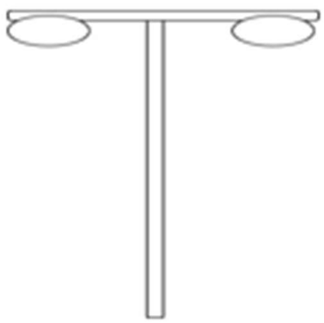
$$\text{Energy Saved} = \frac{432000 - 19143.252}{432000} \times 100$$

$$= 95\% \text{ (approx)}$$

Cost Analysis

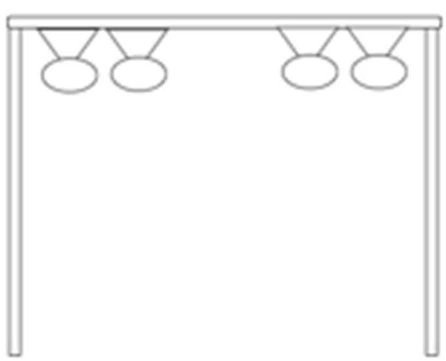


Height (ft)	Cost (Rs.)
5	1680
8	2688
13	4368
16	5975
21	7156

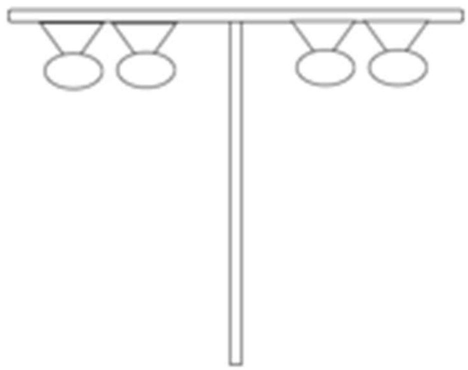


Height (ft)	Cost (Rs.)
5	1960
8	3188
13	5196
16	6372
21	8232

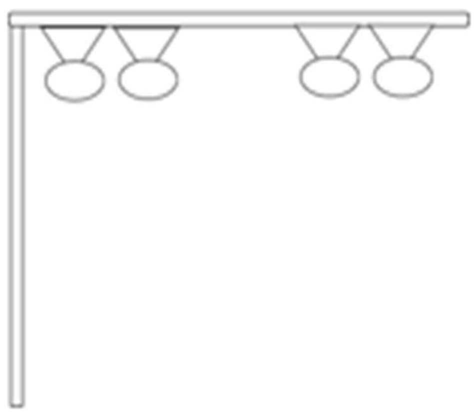
Figure 8: Cost of existing design



Height (ft)	Cost (Rs.)
5	5600
8	8968
13	14568
16	17659
21	19630



Height (ft)	Cost (Rs.)
5	3460
8	5536
13	8995
16	11072
21	13864



Height (ft)	Cost (Rs.)
5	4200
8	6720
13	9635
16	12695
21	15443

Figure 9: Cost for new form designs

From the above analysis, it is observed that the existing form design gives the most optimal solution.

Faculty Review

- Focus was on improving aesthetic values of final model.

Hackathon 2 (Week 11)

Features demonstrated

- Reactive level of intelligence was exhibited.
- Street light intensity variation based on 2 factors - external light intensity using LDR and motion using ultrasonic sensors
- Ultrasonic sensors were used in place of PIR sensors due to better efficiency.
- All sensors were calibrated for optimal performance.
- The two separately functioning modules (LDR and Ultrasonic) were integrated (hardware and software).
- The physical structures of the integrated streetlights was demonstrated for the highway road use case.
- Design was implemented for a road containing a series of five LEDs fitted with all the sensors.
- A mesh topology was used to determine the collective output of the ultrasonic sensors.

Division of Workload

Task	Team Members
Mechanical Design	Sri Chand Anush
Electronics	Abirami Harshitha
Arduino and Documenting	Vinitha Shukrithi

Lessons learnt

1) Separately functioning modules need not function seamlessly when integrated. Mechanical integration of circuits and structures need to be planned carefully and executed with caution.
2) Always procure extra supply of resources like wires for backup to avoid issues like insufficient length of wire.
3) Reduce circuit complexity as far as possible before implementing the physical structure.
4) Avoid loose connections.
5) Testing (hardware, software and electrical connections) at every stage of development is essential to deliver product on time.

New insights

There is significant delay while using PIR sensors to determine the approach of a moving vehicle or person. Ultrasonic sensors on the other hand, will be able to give us quicker and more accurate outputs, resulting in a more efficient product design.

Therefore, the PIR sensors were replaced with Ultrasonic sensors.

Next steps

- Proper integration of physical structure, hardware and software and demonstration of two-way highway use case.
- Implement the final prototype of the proposed solution with focus on aesthetic value and finished look of the final product.

Link for video

https://drive.google.com/open?id=1h_nZHHHS9i1HOVxHQxqHe2VxCW5cmCj_

Week 12

Progress

- Testing and integration of physical structure, hardware and software.
- Proper demonstration of two-way highway use case.
- Fine tuning of code and calibration for accuracy.
- The final prototype was implemented including focus on aesthetic values and overall appearance of the finished product.

<u>**(Week 13 – Final Demo)**</u>

Features demonstrated

- Reactive level of intelligence.
- Street light intensity variation based on external light (using LDR) as well as based on motion – vehicle/human/animal (using Ultrasonic sensors).
- Optimization of product in terms of efficiency, accuracy and cost after application of design concepts like FTA, FMEA, DFSS, etc.
    - Points of potential failure that were identified were eliminated by connecting lights and sensors in a mesh topology and making the design robust.
- Monitoring of energy efficiency
    - The specific use case implemented was shown to have up to 95% energy efficiency. (Comparing with data from previous ethnography)
    - For a more general use case, energy efficiency of 30-35% energy efficiency was observed.
- Cost Analysis
    - It was found that after initial investment, the break-even point for a typical metro city use case was two years.

Software

```
#define trigPin1 12
#define echoPin1 13
#define trigPin2 A5
#define echoPin2 4
#define trigPin3 2
#define echoPin3 3
#define trigPin4 7
#define echoPin4 8

long duration, distance, dval1,dval2,dval3,dval4;

void setup()
{
Serial.begin (9600);
pinMode(trigPin1, OUTPUT);
pinMode(echoPin1, INPUT);
pinMode(trigPin2, OUTPUT);
pinMode(echoPin2, INPUT);
```

```
pinMode(echoPin2, INPUT);
pinMode(trigPin3, OUTPUT);
pinMode(echoPin3, INPUT);
pinMode(trigPin4, OUTPUT);
pinMode(echoPin4, INPUT);
digitalWrite(A5,LOW);
```

```
void loop() {

dval1 = SonarSensor(trigPin1, echoPin1);

dval2 = SonarSensor(trigPin2, echoPin2);

dval3 =SonarSensor(trigPin3, echoPin3);
dval4 = SonarSensor(trigPin4, echoPin4);
Serial.print(dval1);
Serial.print(" - ");
Serial.print(dval2);
Serial.print(" - ");
Serial.println(dval3);
Serial.print(" - ");
Serial.println(dval4);

int val1,val2,val3,val4;
val1=analogRead(A0);
val2=analogRead(A1);
val3=analogRead(A2);
val4=analogRead(A3);
Serial.print(val1);
Serial.print(" - ");
Serial.print(val2);
Serial.print(" - ");
```

```
Serial.println(val3);
Serial.print(" - ");
Serial.println(val4);

int y1,y2,y3,y4,y5;
int i1=0;
  int i2=0;
  int i3=0;
  int i4=0;
  if (val1>=0 && val1<=250)
  i1=1;
  if (val2>=0 && val2<250)
  i2=1;
```

```
if (val3>=0 && val3<=250)
i3=1;
if (val4>=0 && val4<=250)
i4=1;

y1=((i1&&i2&&i4)||(i2&&i3&&i4)||(i1&&i3&&i4)||(i1&&i2&&i3));

int j1=0;
int j2=0;
int j3=0;
int j4=0;
if (val1>=250 && val1<=499)
```

```
j1=1;
if (val2>=250 && val2<=499)
j2=1;
if (val3>=250 && val3<=499)
j3=1;
if (val4>=250 && val4<=499)
j4=1;

y2=((j1&&j2&&j4)||(j2&&j3&&j4)||(j1&&j3&&j4)||(j1&&j2&&j3));

int k1=0;
int k2=0;
int k3=0;
int k4=0;
if (val1>=500 && val1<=749)
k1=1;
if (val2>=500 && val2<=749)
k2=1;
if (val3>=500 && val3<=749)
k3=1;
if (val4>=500 && val4<=749)
k4=1;

y3=((k1&&k2&&k4)||(k2&&k3&&k4)||(k1&&k3&&k4)||(k1&&k2&&k3));

int m1=0;
int m2=0;
```

```
int m3=0;
int m4=0;
if (val1>=750 && val1<=999)
m1=1;
if (val2>=750 && val2<=999)
m2=1;
if (val3>=750 && val3<=999)
m3=1;
if (val4>=750 && val4<=999)
m4=1;

y4=((m1&&m2&&m4)||(m2&&m3&&m4)||(m1&&m3&&m4)||(m1&&m2&&m3));

int n1=0;
int n2=0;
int n3=0;
int n4=0;
if (val1>=1000)
n1=1;
if (val2>=1000)
n2=1;
if (val3>=1000)
n3=1;
if (val4>=1000)
n4=1;

y5=((n1&&n2&&n4)||(n2&&n3&&n4)||(n1&&n3&&n4)||(n1&&n2&&n3));
```

```

  Serial.print("y1:");Serial.println(y1);
  Serial.print("y2:");Serial.println(y2);
  Serial.print("y3:");Serial.println(y3);
  Serial.print("y4:");Serial.println(y4);
  Serial.print("y5:");Serial.println(y5);
if(y1==1)
  {
    if(dval1==1 && dval2==0 && dval3==0 && dval4==0)
    {
      analogWrite(6,255);
      analogWrite(5,128);
      analogWrite(9,64);
      analogWrite(10,0);
    }
    else if(dval1==1 && dval2==1 && dval3==0 && dval4==0)
    {
      analogWrite(6,128);
      analogWrite(5,255);
      analogWrite(9,128);
      analogWrite(10,64);
    }
    else if(dval1==0 && dval2==1 && dval3==1 && dval4==0)
    {
      analogWrite(6,0);
      analogWrite(5,128);
      analogWrite(9,255);
```

```
      analogWrite(10,128);
    }
    else if(dval1==0 && dval2==0 && dval3==1 && dval4==1)
    {
      analogWrite(6,0);
      analogWrite(5,0);
      analogWrite(9,128);
      analogWrite(10,255);
    }
    else if(dval1==0 && dval2==0 && dval3==0 && dval4==1)
    {
      analogWrite(6,0);
      analogWrite(5,0);
      analogWrite(9,0);
      analogWrite(10,255);
    }
```

```
    else if(dval1==0 && dval2==0 && dval3==0 && dval4==0)
      {
      analogWrite(6,0);
      analogWrite(5,0);
      analogWrite(9,0);
      analogWrite(10,0);
    }
  }

   if(y2==1)
  {
```

```
    if(dval1==1 && dval2==0 && dval3==0 && dval4==0)
    {
      analogWrite(6,192);
      analogWrite(5,96);
      analogWrite(9,32);
      analogWrite(10,0);
    }
    else if(dval1==1 && dval2==1 && dval3==0 && dval4==0)
    {
      analogWrite(6,96);
      analogWrite(5,192);
      analogWrite(9,96);
      analogWrite(10,32);
    }
    else if(dval1==0 && dval2==1 && dval3==1 && dval4==0)
    {
      analogWrite(6,0);
      analogWrite(5,96);
      analogWrite(9,192);
      analogWrite(10,96);
    }
    else if(dval1==0 && dval2==0 && dval3==1 && dval4==1)
    {
      analogWrite(6,0);
      analogWrite(5,0);
      analogWrite(9,96);
      analogWrite(10,192);
```

```
    }
    else if(dval1==0 && dval2==0 && dval3==0 && dval4==1)
    {
      analogWrite(6,0);
      analogWrite(5,0);
      analogWrite(9,0);
      analogWrite(10,192);
    }
    else if(dval1==0 && dval2==0 && dval3==0 && dval4==0)
      {
      analogWrite(6,0);
      analogWrite(5,0);
      analogWrite(9,0);
      analogWrite(10,0);
    }
  }

   if(y3==1)
  {
    if(dval1==1 && dval2==0 && dval3==0 && dval4==0)
    {
      analogWrite(6,128);
      analogWrite(5,64);
      analogWrite(9,16);
      analogWrite(10,0);
    }
    else if(dval1==1 && dval2==1 && dval3==0 && dval4==0)
```

```
    {
      analogWrite(6,64);
      analogWrite(5,128);
      analogWrite(9,64);
      analogWrite(10,16);
    }
    else if(dval1==0 && dval2==1 && dval3==1 && dval4==0)
    {
      analogWrite(6,0);
      analogWrite(5,64);
      analogWrite(9,128);
      analogWrite(10,64);
    }
    else if(dval1==0 && dval2==0 && dval3==1 && dval4==1)
    {
      analogWrite(6,0);
      analogWrite(5,0);
      analogWrite(9,64);
      analogWrite(10,128);
    }
```

```
    else if(dval1==0 && dval2==0 && dval3==0 && dval4==1)
    {
      analogWrite(6,0);
      analogWrite(5,0);
      analogWrite(9,0);
      analogWrite(10,128);
```

```
    }
    else if(dval1==0 && dval2==0 && dval3==0 && dval4==0)
      {
      analogWrite(6,0);
      analogWrite(5,0);
      analogWrite(9,0);
      analogWrite(10,0);
    }
  }

if(y4==1)
  {
    if(dval1==1 && dval2==0 && dval3==0 && dval4==0)
    {
      analogWrite(6,96);
      analogWrite(5,48);
      analogWrite(9,16);
      analogWrite(10,0);
    }
    else if(dval1==1 && dval2==1 && dval3==0 && dval4==0)
    {
      analogWrite(6,48);
      analogWrite(5,96);
      analogWrite(9,48);
      analogWrite(10,16);
    }
```

```
    else if(dval1==0 && dval2==1 && dval3==1 && dval4==0)
    {
      analogWrite(6,0);
      analogWrite(5,48);
      analogWrite(9,96);
      analogWrite(10,48);
    }
    else if(dval1==0 && dval2==0 && dval3==1 && dval4==1)
    {
      analogWrite(6,0);
      analogWrite(5,0);
      analogWrite(9,48);
      analogWrite(10,96);
    }
```

```
    else if(dval1==0 && dval2==0 && dval3==0 && dval4==1)
    {
      analogWrite(6,0);
      analogWrite(5,0);
      analogWrite(9,0);
      analogWrite(10,96);
    }
    else if(dval1==0 && dval2==0 && dval3==0 && dval4==0)
      {
      analogWrite(6,0);
      analogWrite(5,0);
      analogWrite(9,0);
```

```
      analogWrite(10,0);
    }
  }

if(y5==1)
{
   analogWrite(6,0);
      analogWrite(5,0);
      analogWrite(9,0);
      analogWrite(10,0);
}
}


int SonarSensor(int trigPin,int echoPin)
{
digitalWrite(trigPin, LOW);
delayMicroseconds(2);
digitalWrite(trigPin, HIGH);
delayMicroseconds(10);
digitalWrite(trigPin, LOW);
duration = pulseIn(echoPin, HIGH);
distance = (duration/2) / 29.1;
if (distance<=20)
return(1);
else
```

Hardware

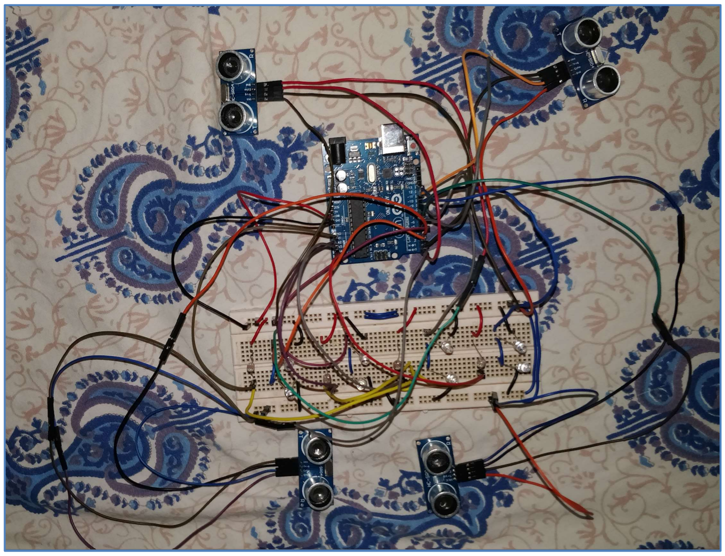


Figure 10: Testing Stage

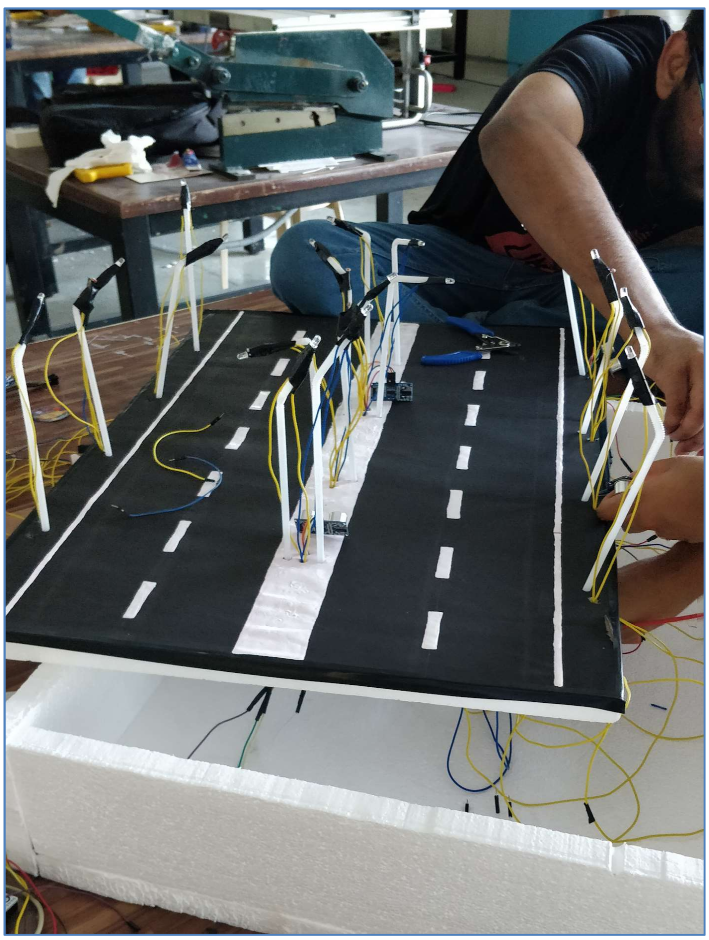
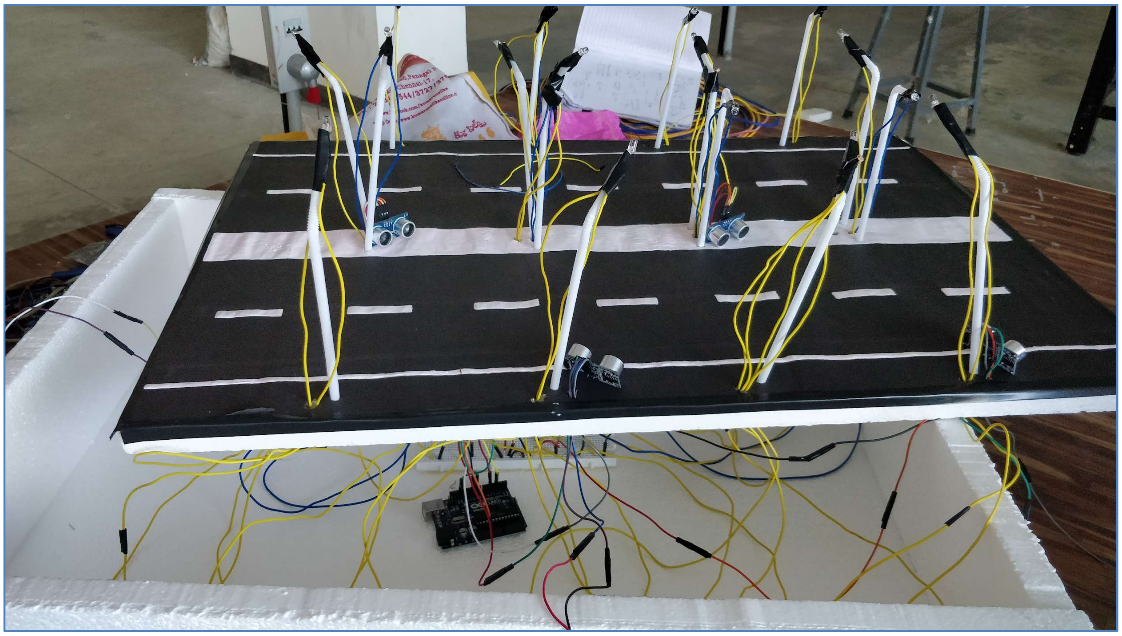
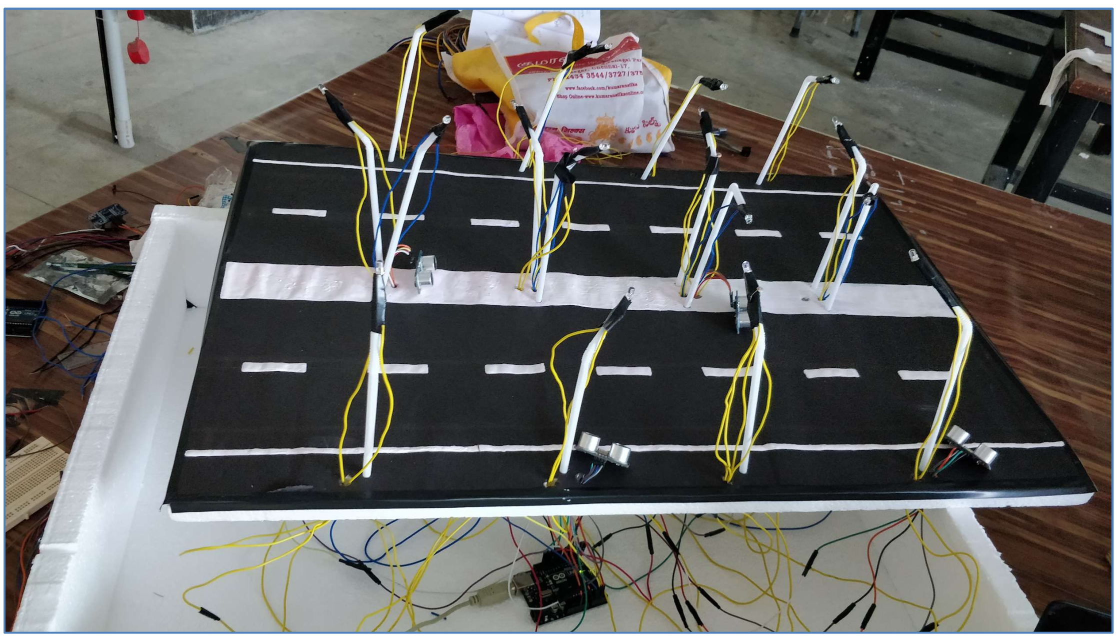


Figure 11: Connections Stage





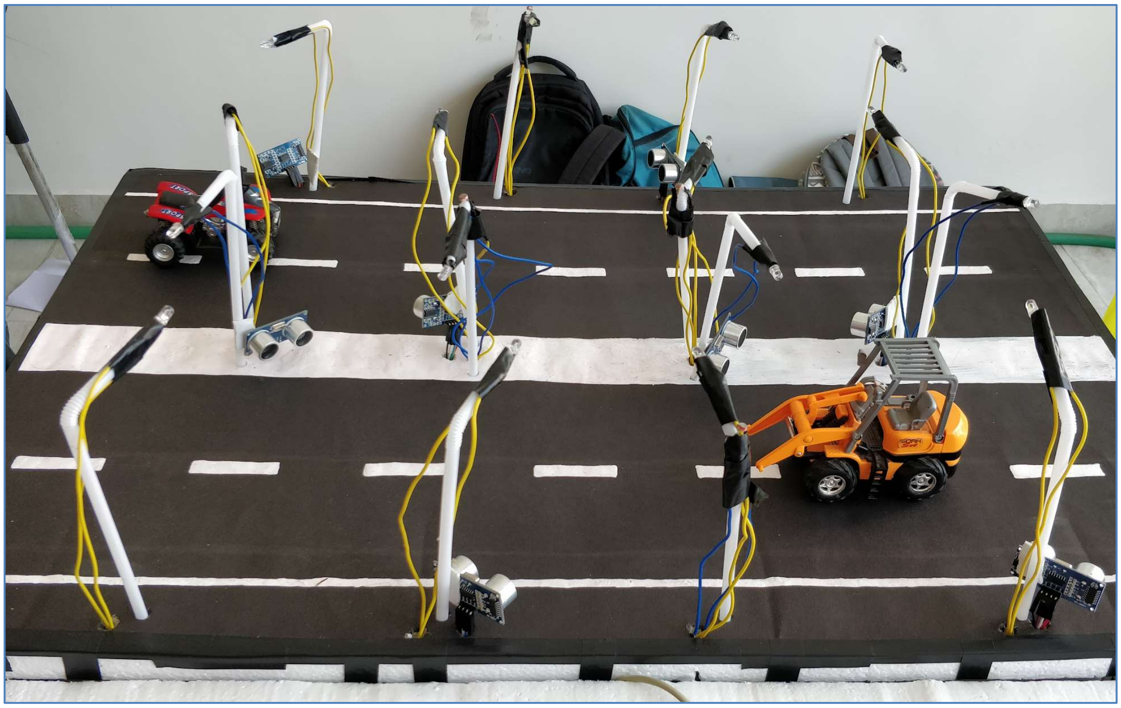
Link for videos of testing stage: Click here


SPORT

Final Stage (EHIPASSIKO 2019)

Video Link

https://drive.google.com/open?id=1GydSekZeFtjcHQgwwpI1SfOaiNmpVUSX



Lessons learnt

- Loopholes in technology
  a) Regular maintenance and cleaning required. Accumulation of dust over LDR leads to malfunction of sensors.
  Solution - Dust resistant casing or coating.
  b) Occurrence of power surges during switching (between ON -> OFF) adversely affects life-time of product.
  Solution - To keep light intensity low during night instead of turning OFF permanently.

New Insights

- The same concept can be used in a classroom scenario
  a) In order to improve energy efficiency and decrease wastage of power, these lights can be fitted in a classroom and deployed such that the lights do not function when the classroom is empty.
  b) As our product used Ultrasonic sensors which detect proximity instead of motion, this would be ideal as the lights would function when students are sitting inside the class.
  c) In case of motion detection, this would not be possible as the lights would turn off when there is no motion inside the classroom.

- Extension of concept to be used in the assembly line of a manufacturing set up.

Faculty and Visitor Feedback

Faculty Name	Feedback	Signature
Raghuraman	Fantastic work	
Anand. L [ERICSON INDIA] External	Very practical & useful idea. Should implement in campus to bring forth the benefits — which can be very good data point to sell the idea for bigger scale.	
Prof B. [illegible]	Excellent	

Faculty Name	Feedback	Signature
Dr. T.S - Narayanan	- Work on Switching Power Surge.	
Rajesh Kunnath [Radio room]	Nice concept. Well executed	
SEKAR Caterpillar	Good Concept	

Arul, [Asst. Manager NSIC] External.	Good idea. may be implemented & extended to real time project.	[illegible]
Dr. Asutosh Kar	Nice work. Keep it up and get more success in life. Best wishes Akr	[illegible]
J. Chandrasekaran [Watsan. in] — Will complete team start a company?	Can connect you to 2nd largest street light mfr. Chandra@watsan.in — Sensors to be locally manufactured — What you need in terms of integration with existing street light? —	[illegible]