Smart Highways: Harvesting Electricity using Speeding Vehicles

Yashvi Thakkar, Anisha Sai Sistla, Faiz Palwala, Krithika Balasubramanian, Suhavi Singal, Animesh Aggarwal, Neelesh Gupta, Santhi V

***Abstract*: This study deals with harvesting electricity using speeding vehicles and thus making facilitating towards smart highways. Considering the shortage of electricity and current rate of over exhaustion of fossil fuels, renewable resources need to be used efficiently to meet the current needs and future demands. The model proposed consists of a turbine which is attached to a generator which will further converts kinetic mechanical energy to electrical energy. There are various new mechanical designs and materials proposed for the turbine which will reduce the cost with the same efficiency. There is a safety circuit which will prevent any damage caused by certain voltage fluctuations and bidirectional rotor motion. This is further connected to a charging circuit and Arduino current sensor and Arduino voltage sensor which works on voltage divider rule. NodeMCU is used to log and store data on ThingSpeak API. This helps us in keeping a tab of certain parameters like current, voltage etc which can be used to charge a battery and transmit it to nearby villages, provide charging hubs on the highways and act as charging stations for electrically powered cars.**

***Index Terms*: Harvest Electricity, NodeMCU, Smart Highways ,Speeding vehicles, ThingSpeak IOT platform,.Wind produced from vehicles.**

I. INTRODUCTION

Life in the 21st Century revolves around electricity, it's really hard to imagine any and all kinds of productivity without it.

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***** Correspondence Author

Yashvi Thakkar*, School of Computer Science and Engineering, Vellore Institute of Technology, Vellore, India

Anisha Sai Sistla, School of Computer Science and Engineering, Vellore Institute of Technology, Vellore, India

Faiz Palwala, School of Computer Science and Engineering, Vellore Institute of Technology, Vellore, India

Krithika Balasubramanian, School of Computer Science and Engineering, Vellore Institute of Technology, Vellore, India

Suhavi Singal, School of Computer Science and Engineering, Vellore Institute of Technology, Vellore, India

Animesh Aggarwal, School of Computer Science and Engineering, Vellore Institute of Technology, Vellore, India

Neelesh Gupta, School of Computer Science and Engineering, Vellore Institute of Technology, Vellore, India

Santhi V, School of Computer Science and Engineering, Vellore Institute of Technology, Vellore, India

Yet electricity cuts are probably one of the biggest hurdles that India faces in its bid to be a superpower [1].India gets most of its electricity from coal-based electricity plants, which in its self is a dying resource and due to the nature of the economics of supply-demand, the ever-rising prices for fossil fuels, it holds the potential to drive the economy back to the ground. But let's reflect a bit, India (as of writing) is a country of 1.34 Billion people, second only to China which of course has a higher land area to play with. This gives our country a population density of about ~400 people per square km, and that's a lot of potential electricity users [2]. In layman's terms building out an electricity grid around a technology (albeit not traditional) is simply not sustainable. The key here is diversification, we can't depend on a single energy resource for a population of this size, it's all about the efficiency with which we can harvest electricity of our surrounding. And with no pre-existing infrastructure to adhere to, India finds itself with this opportunity to lead the way in terms of innovation, this opportunity to say the least is exciting.

Now, in terms of the motivation for this paper wasn't to challenge what we can term as bulk energy producers i.e. fossil fuels, nuclear energy etc. but was rather to offer a solution that can be applied to more remote locations (in this case highways), recycling a lot of energy and redistributing it. Basically, a solution that compensates rather than replace a traditional power sources, in our country bid to bring power to the next quarter billion people. Renewable energy is the future, but in the present it's just not dependable yet, as we are harvesting energy from the nature which in its very nature is unpredictable [3]. It's important to have redundancy with the key being areas being a self-sufficient when it comes of energy generation, this is the perfect segue into talking about the proposed solution. The idea is to harvest electricity off speeding cars off a highway, transporting electricity to remote location like these highways was reported to be one of the biggest causes of energy loss, so what if these highways were self-sufficient. Other potential applications include having it power charge stations for electric cars, sending power back to the electric grid the possibilities are endless.

II. GENERATION TECHNIQUES

[5] One of the current systems which was proposed in the year 2015, proposes an external advanced H-bridge convertor that must be added on the vehicle.

This will capture all the air that is being collected in the turbine while the vehicle is moving and store it inside the car which will help recharge the battery of the car. [8] Another work in the same category which was published in the year 2017, proposes a wind turbine to be manually attached to a car. The wind turbine attached is connected to a battery which stores the energy which is collected from the moving car, this doesn't depend on the geographic location of the car. [9] The paper which was published in the year 2014 proposes a wind turbine to be attached to a vehicle and it manually stores energy in the battery which recharges the car. [23] An idea which was proposed in a paper, which was published in the year 2011, suggests Vertical Axis Wind Turbine (VAWT) The VAWT is combined with circle type alternator is set on the highway street dividers. As the wind is forced by passing vehicles from the two sides, the wind speed on the inside spot of the highway roads will be more than at the person on foot strolling path. This wind is compelled to the VAWT from two headings intensely however this VAWT makes utilization of both the wind directions and rotates in one direction only. [6][7] Some papers suggested in the change of the shape and materials in the blades. [10] In the paper written by Bas de Jong in the year 2014, the author suggests for the turbine blades to be in 'helix shaped'. The VAWT is combined with disc type alternator is put on the highway road dividers. As the wind is constrained by passing vehicles from the two sides, the wind speed on the inside spot of highways roads will be more than at the pedestrian walking lane. This wind is compelled to the VAWT from two headings intensely yet this VAWT makes utilization of both the wind directions and rotates in one direction only.[16] In another paper proposed by Theodore F Wiegel, Kenneth C Stevens in the year 2012, The device ideally utilizes on a level plane or vertically mounted Savonius type or helical-turbine-type rotors joined to electrical generators so as to catch the wind and produce electrical vitality.[19] According to a study proposed in the paper, There are 14,300 trains working every day on 63,000 course kilometers of railroad in India. This strategy would be equipped for creating 1,481,000 megawatt (MW) of intensity in India alone. Changing the shape of the blades captures more air produced thus increasing the generation of electricity. [23] The curvy darrieous cutting edges are associated with the two finishes of the bearing which is able to rotate on its own axis. In expressways, the vehicles proceeding onward two different directions makes the wind turbine to turn all the more adequately all alone hub in just a single course for example clockwise heading. The dynamo is associated with either upper part or lower some portion of the wind turbine which works on Fleming's left-hand principle of electromagnetic enlistment. A few papers have focused on electricity generation using the wind energy produced by trains. [17] A paper written by Shridhar Jagdale and Krutika Deshmukh proposed the use of wind vitality delivered via trains to be used for generating power. Because of the development of train, the breeze will stream the other way of train and then blows towards the sharp edges of the blades of turbine, which in turn, turns the pole associated with it. The pole is in connected via circuit to an alternator. In this case energy is produced at cheaper cost and even the vibrations are used for generating electricity. [6] Another idea that was put forward by the students of Florida International University was Highway wind turbines. Installation of wind turbines can be done in such a way that they get powered by the flow of air from both sides of the road which ultimately results in generation of electricity, this can be achieved by placing the turbines at the medians. The design can be applied to the streetlights as well by installing them with turbines to capture the wind and generate electricity to run the streetlights along with other applications of the energy so generated. Since the changes in the source of wind are irregular wind source will change irregularly, a system which can store the electricity that has been produced will be developed in order to obtain a regular power source, electricity from which can be effectively distributed. [11] Another research came up with the concept of Vehicular Wind Energy Converter (VWEC). The VWEC is a triple-bladed, drag type, vertical-axis wind turbine that generates electricity from wind blowing over vehicles that are moving with the least required speed. The turbine here, is effectively an enclosed gadget that only contains the inlet and outlet for the wind. The main advantage is that it is not very expensive to manufacture and can be improved to yield great amount of power. [13] Some other research work done by C.Sakthivel and Dr. T. Venkatesan uses wind pressure experienced by rapidly moving vehicles and focusing this pressure into the wind turbine. Vehicles moving with at least the requisite speed compress the air present in front of them and then push the air present from the sides thus making a vacuum at their rear end and their sides as they moves ahead. The kinetic energy resulting from the movement of air is then used to produce electricity. [14] According to a paper written by Osita Patrick Eze and Dr. Ramin Amali in 2014, electrical energy can be produced from vehicle induced wind gust (VIWG). It is described as a set up developed in accordance with the concept of simple ratchet mechanism which demonstrates that the energy present in VIWG can be tapped and electricity can be generated from it. The device captures the wind energy from wind gust which rotates the main shaft. The primary challenge is to transfer the rotatory motion from the main shaft to the rotor in an efficient manner. [18] A research done by V. V. Thang and N. T. D. Thuy proposes a planning model that supports an optimized distribution set-up that makes use of DG in the competitive electrical energy market. The said model is capable of determining the size of equipment along with the time frame required to upgrade the components of the distribution system and also choose DG technologies that match the power variable constraints of DG. The objective function of this is to minimize the complete life cycle price of the respective investment project.

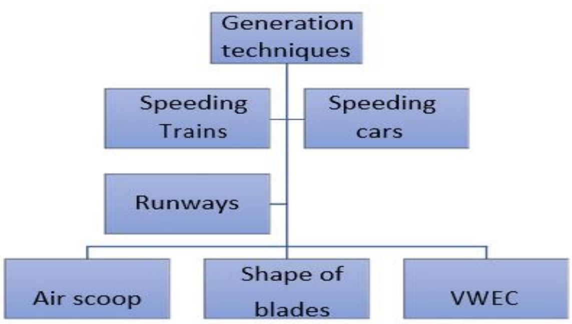

Fig 1. Generation areas and techniques

Fig 1 describes the areas where wind generated can be used to harvest electricity. Furthermore, talking about the trends seen so far, they have been classified into three broad categories as shown in the figure. These three categories have their own pros and cons. Comparative Analysis has been done for these three categories in table 1 which is as follows.

A. *Comparative Analysis*

Features	**Air Scoops**	**Shapes of Blades**	**VWEC(Vehicular Wind Energy Generation)**
Unique Features	External device, added on the top of the vehicle	Shape of the blade is changed up to certain extent	Disc type alternator placed on middle of the road
Cost of installation	High(Must be installed while the car is being manufactured)	Very high (Carbon fibers are very expensive)	Medium to high (Not very expensive to manufacture)
Feasibility	Feasible in small countries (less cars, less manufacturers)	Changing shape of blades of windmill in already existing wind farm will be time consuming	Feasible as compared to air scoops and shape of blades.
Advantages	Reduction in pollution, Maximum amount of energy is recycled	Larger gust of wind is trapped, hence high throughput	Greater power is produced.
Disadvantages	Not efficient as proved theoretically, cannot support huge gust of wind in one go.	Not cost efficient, Time consuming	Open shaft is harmful for birds and various animals especially in the night time.

Table 1

III. Proposed Work

This project aims at using the wind energy produced by speeding vehicles especially on highways which otherwise will be wasted in smart cities because WiFi connection is required to analyze and store data on Internet of things platform. The units which are described below will be installed in the walls which separate the service road and the main highway as well the dividers so the wind produced by vehicles speeding at about 80-120 km per hour which otherwise will be wasted can be used to harvest electricity. The basic model will consist of seven modules which are as follows: *Generating Circuit*

1) Mechanical design consideration
2) Measurement of Parameters
3) Uploading data to Internet Cloud
4) Storing Energy in Battery
5) Showing and logging data on IOT platform
6) Analysis and using the stored battery

A. *Generating Circuit*

The generating circuit will consist of basic circuit components like capacitors and transistors. A safety circuit will also be added to the generating circuit in case the wind speed exceeds the limits and damages our main circuit. It consists of the turbine which rotate due to the fast-moving vehicles. The generator will then convert the kinetic rotary motion to electricity. The capacitor acts a smoothening agent and is part of the safety circuit which will prevent the abrupt motion of the turbine.

B. *Mechanical Design Considerations*

Mechanical considerations include designing the overall system for the blades includes the casing of the blades and its shape for more and more intake of air when the rotor blades rotate. Cost of installing a turbine has been and ever evolving issue since wind has been used for generating electricity. The turbines are made of carbon and glass resins which is lightest and one of the costliest fibers. In coming years, Coal drawn Steel tends to provide all the properties of carbon and glass fibers and moreover is way cheaper.

C. *Measurement of Parameters*

For measuring parameters like current and voltages, a separate circuit will be made which will consist of a basic voltage divider circuit and a Arduino voltage sensor to measure the voltage. ACS712 will be used to measure the current and hence the amount of electricity generated.

D. *Uploading data to Internet cloud*

The pins of the current sensor and the voltmeter will be connected to the NODEMCU and the data will be monitored continuously by logging into the ThingSpeak API. ThingSpeak is an open source Internet of Things platform which has MATLAB analysis tools which help us plotting graphs and help us analyze it.

E. *Storing Energy in Battery*

This comprises of a charging circuit. The charging circuit includes two light emitting diode and a transistor BC548. The light emitting diodes are used for a reference purpose to know when the battery is charging and when it needs to be charged in a prototype model. For real time model, the continuous monitoring of the parameters will be done by uploading them on a cloud-based platform using NODEMCU. This module is used to charge a battery say LiCd or any such battery. The diode ensures unidirectional flow of the current. The red led will light when the battery isn't charge and while is it charging/ charged green led will light. Current will flow only when it is in forward bias.

F. *Showing and logging data on IOT Platform*

The data is uploaded on the NODEMCU which can be accessed and depicted by the means of a bar graph or a pie chart, this will help us keep track of data and also compare the results every time we log in. The data can be fetched from any part of the world. This will further help us in deciding whether to install more units on certain busy highways. The proposed implementation also employs, ThingSpeak which is a free to use cloud service cantered around IoT applications.
The REST API is used to read the sensor data from the NodeMCU, which is turn in used for analysis (ThingSpeak also provides web app that let you analyze and visualize data via MATLAB) provided experimental proof over the validity of our proposal.

G. *Analysis and using the stored battery*

The stored energy and the data can give fruitful results in dividing the energy generated in certain nearby villages, or in order to provide charging hubs on the highways or to lighten the streetlights. Ten years down the line, these units when installed in arrays/batches can further be changed into charging units for the electrically powered

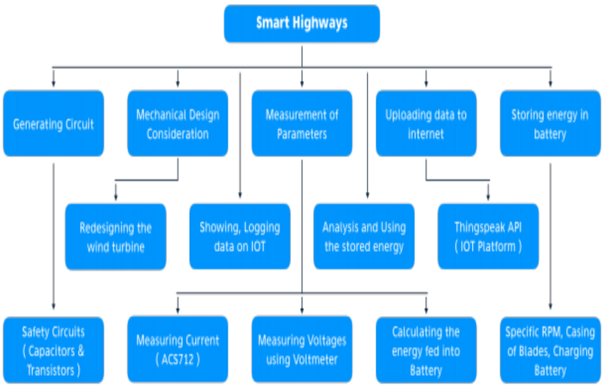

Fig 2. Modular diagram

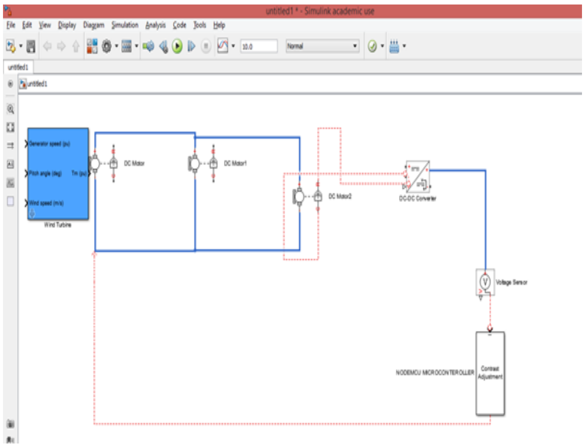

Fig 3. Generating Circuit

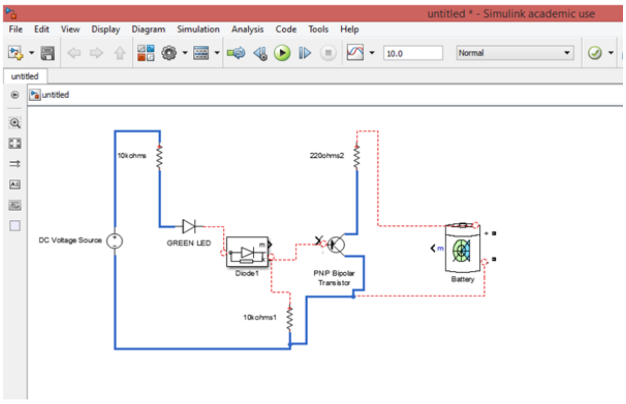

Fig 4.Charging Circuit

Fig 2 shows the modular split up of the proposed model and further Fig3 depicts the general circuit which will be installed on the highways in an array/ batches of threes. The units in each batch can be further increased based on the number of vehicles passing by. Fig4 refers to the charging circuit which will be used to charge the battery

IV. Results & Discussion

We have successfully achieved the desired output. The circuit diagrams shown below is the experimental setup or prototype. Such arrays will be installed on the side road of the highways. For this experiment, a normal blow dryer has been used to replace the wind produced by speeding vehicles and this is further recorded on ThingsSpeak API. This data can be further exported or used by various officials to distribute the amount of electricity generated.

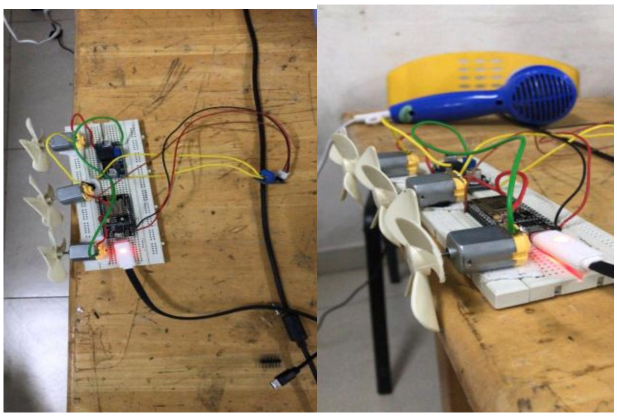

Fig 5. Circuit

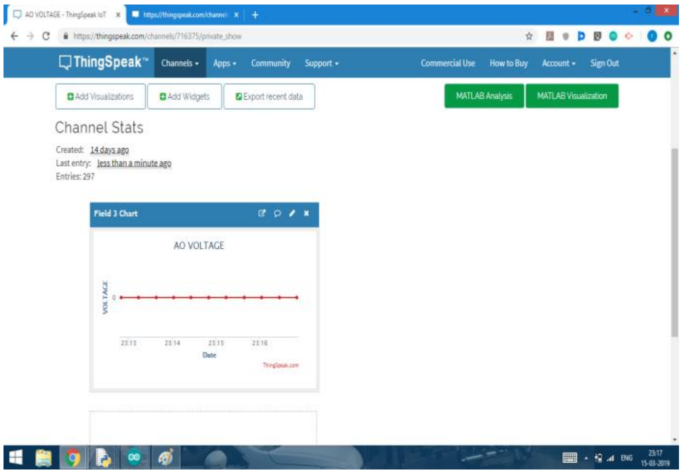

Fig 6. Output before speeding cars pass the turbines

The graph depicted in Fig 6, shows a Date(time on a particular day) vs voltage graph. Initially, when no speeding vehicles pass through the highway, the graph is parallel to X-axis justifying the graph obtained. Further when the speeding cars start passing across the highways, the arrays of the above described setups are installed the variations in the voltage produced are shown in Fig7.

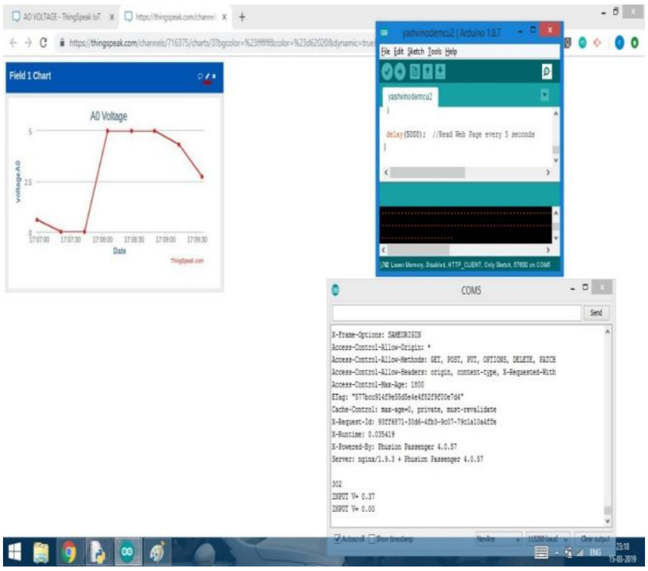

Fig 7. Output recorded when cars travel by

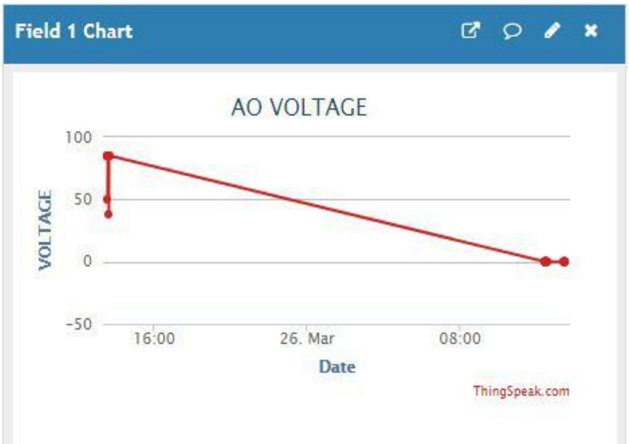

Fig 8a: Output graph obtained (Voltage Vs Time)

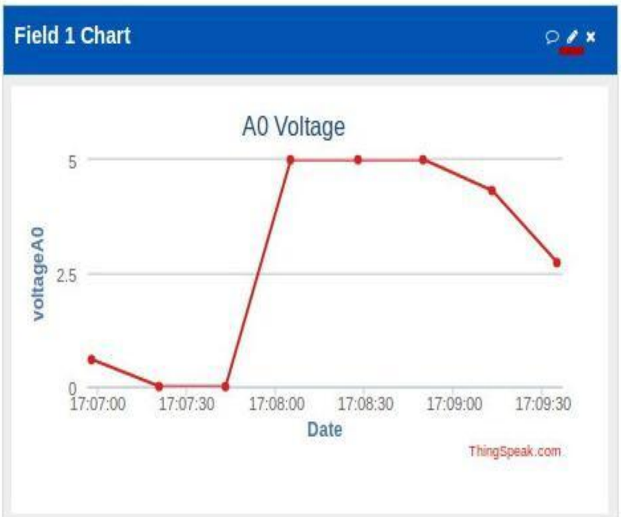

Fig 8b: Output graph obtained(Voltage Vs Time

Here the COM5 consists of the basic X- requests and server calls to the IOT platform. Once a successful connection is established, it starts displaying the input voltage i.e the voltage harvested by speeding cars. The NodeMCU frame, reads the ThingSpeak platform after 5 seconds and records the changes. A varying date(time) vs voltage graph is depicted in fig 7. The initial generation of the electricity will be low, but when seen from a ten years down the line perspective, when the concept of DC cars will be prevalent in most of the areas, this can turn out to serve as a charging station. The data generated in forms of graphs, can be accessed by various members through generation of a secret key and the data can be converted into csv format. This can further help in deciding the split up of the surplus amount of electricity and effective supply of it. The graph shown in figure 8 is between voltage and time generated simultaneously as soon as speeding vehicles cross the array of turbines in the highways

V. CONCLUSION

All the practices which have been listed above are nearly not feasible or they are feasible only to certain areas. Our proposed system can be installed on all types of terrains. It aims a being cost effective as well as providing high throughput. It will tend to overcome the circuit breakage by usage of a safety circuit. By substituting the turbine material and casing it after changing the shapes of the blades, will help in trapping more wind. Since it will be installed in the walls separating the service roads and the highways, the rotor shaft will not cause any harm to animals and birds. Moreover, since the data will be continuously monitored and analyzed, further enlargement of the units can be done and power will be sent to the places by proper calculation so that it meets their energy needs.

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AUTHORS PROFILE

Yashvi Thakkar pursuing BTech in Computer Science and Engineering in Vellore Institute of Technology, Vellore notably worked on Spot A Spot - Using Single Shot Multibox Detector, Springer AISC series

Anisha Sai Sistla pursuing BTech in Computer Science and Engineering in Vellore Institute of Technology, Vellore notably worked on Image captioning using deep learning

Faiz Palwala, pursuing B.Tech Computer Science at Vellore Institute of Technology. He is passionate in tech pursuing projects in Data Sciences and NLP, notably worked on an Alexa Skill to bring knowledge base of services like Wolfram to the masses in a conversational form.

Krithika Balasubramanian currently pursuing BTech in Computer Science and Engineering in Vellore Institute of Technology, Vellore. Notably worked in Obstacle detection using Stereo Vision, Deep learning - Plant species Recognition

Suhavi Singal, currently pursuing Btech, Computer Science from Vellore Institute of Technology. Inclined towards upcoming fields like Internet of Things and Artificial Intelligence and thus have done technical projects related to the same. Has good experience in the field of Networking and routing , specialization in Wi-Fi security and familiar with some new software like Cisco Packet Tracing.

Animesh Aggarwal, currently pursuing B.Tech in Computer Science and Engineering from Vellore Institute of Technology, Vellore. Have worked in the field of machine learning and have developed related project like question answering model, acoustic scene classifier, opticla character recognition model.

Neelesh Gupta ,currently pursuing Bachelor of Technology - BTech,Computer Engineering in Vellore Institute of Technology. Notable research works Green synthesis, characterization and antifungal and photocatalytic activity of Pithecellobium dulce peel–mediated ZnO nanoparticles

V. Santhi has received her Ph.D. in Computer Science and Engineering from VIT University, Vellore, India. She has pursued her M.Tech. in Computer Science and Engineering from Pondicherry University, Puducherry. She has received her B.E. in Computer Science and Engineering from Bharathidasan University, Trichy, India. Currently she is working as Associate Professor in the School of Computing Science and Engineering, VIT University, Vellore, India. She has authored many national and international journal papers and one book. She is currently in the process of editing two books. Also, she has published many chapters in different books published by International publishers. She is senior member of IEEE and she is holding membership in many professional bodies like CSI, ISTE, IACSIT, IEEE and IAENG. Her areas of research include Image Processing, Digital Signal Processing, Digital Watermarking, Data Compression, Data Mining and Computational Intelligence.