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SPEED CONTROL OF DC MOTOR USING ANT COLONY OPTIMIZATION ALGORITHM

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***Abstract*— In this paper, due to its excellent speed control characteristics, the DC motor has been widely used in industry even though its maintenance costs are higher than the induction motor. As a result, speed control of DC motor has attracted considerable research and several methods have evolved. Although the parameters of high frequency interference model of DC motor could be received by mathematical computation, these parameters are not accurate. We could consider that parameters are optimized base on solution space received by mathematical analysis, and in this paper we propose Ant Colony Algorithm which is well suited to this optimization process. The construction process of ACA solution is a course finished step by step. This algorithm may turn the prior knowledge based solution space to full account and deal with constrained conditions conveniently in this course. Ants could modulate dynamically next junction that can be referred in construction process, so it will guarantee accuracy and feasibility of solution. This algorithm adopts positive feedback mechanism in order to implement intelligent searching and global optimization.**

***Index Terms*— DC motor, DC/DC buck converter, hierarchical controller, Ant Colony Algorithm.**

I. INTRODUCTION

Today industries are increasingly demanding process automation in all sectors. Automation results into better quality, increased production and reduced costs. The variable speed drives, which can control the speed of A.C/D.C motors, are indispensable controlling elements in automation systems. Depending on the applications, some of them are fixed speed and some of the variable speed drives.

The variable speed drives, till a couple of decades back, had various limitations, such as poor efficiencies, larger space, lower speeds, etc., However, the advent power electronic devices such as power MOSFETs, IGBTs etc., and also with the introduction of micro controllers with many features on the same silicon wafer, transformed the scene completely and today we have variable speed drive systems which are not only in the smaller in size but also very efficient, highly reliable and meeting all the stringent demands of various industries of modern era.

Direct currents (DC) motors have been used in variable speed drives for a long time. The versatile characteristics of dc motors can provide high starting torques which is required for traction drives. Control over a wide speed range, both below and above the rated speed can be very easily achieved. The methods of speed control are simpler and less expensive than those of alternating current motors.

DC drives are less complex as compared to AC drives system. DC motors are normally less expensive for low horsepower ratings. DC motors have a long tradition of being used as adjustable speed machines and a wide range of options have evolved for this purpose. DC motors are conveniently portable and well fit to special applications, like industrial and machineries that are not easily run from remote power sources.

In many industrial applications, dc-motors serve as simple devices for implementing velocity tracking tasks. Feedback control schemes, typically, are of the proportional–integral (PI) and proportional–integral–differential (PID)-type. Usually, the voltages for the speed control is supplied by thyristor-based phase controlled rectifiers operated at higher switching frequencies and are designed to provide a continuous armature current under various load situations [10].

Linear regulators are unattractive in modern electronic applications due to high dissipation, transformer size, and large storage capacitors requirements for nominal power operation values, aside from the fact that they cannot provide the extended hold-up time required for the controlled shutdown in digital storage systems. The buck power converter is an appropriate alternative for the dc-to-dc bus voltage regulation as it has low internal losses and hence high-power conversion efficiency [1]. Moreover, the buck–buck converters are a reliable alternative to simultaneously regulate two dc output voltage signals normally required in electronic applications.

The buck–buck topologies require an adequate control scheme to achieve the required output voltage regulation especially under the action of load variations. Therefore, the buck topology together with a proper control scheme can provide, among other features, an efficient energy managing and robustness against [5]. The speed of DC motors can also be controlled by using controllers such as differential flatness control [4].

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II. LITERATURE SURVEY

J. Linares-Flores et al has described in the paper " DC motor velocity control through a DC/DC power converter", a design for smooth angular velocity controllers for a dc/dc Buck converter–dc motor system, wherein the effectiveness of the proposed controllers was verified only by numerical simulations. A smooth starter, based on the differential flatness approach, to regulate the velocity of a dc motor powered by a dc/dc Buck converter was presented. This starter was designed through a simplified second-order model, obtained by considering the motor armature inductance and the converter capacitor current to be negligible. Similarly they introduced an average GPI control law, implemented through a Σ−Δ modulator, for the angular velocity trajectory tracking task, exploiting the flatness of the combined system. To accomplish this, they employed the mathematical model obtained. Likewise, for the same system and task, the design of a dynamic output feedback controller was presented based on a fourth-order model deduced carried out by using the energy shaping and damping injection method.

*H.ElFadil et a*l has described in the paper, "Accounting of DC/DC power converter dynamics in DC motor", a regulator based on the back stepping technique and a fourth-order model of the global system. Additionally, both non adaptive and adaptive versions were designed. They showed, through numerical simulations where the PWM was used, that the adaptive version deals better with load torque changes. Nevertheless, neither smooth references nor parametric uncertainties of the global system were considered.

Jesus Linares-Flores et al has described in the paper, "Load torque estimation and passivity-based control of a boost converter / DC motor combination", an algebraic approach for the fast feed-forward adaption of the angular velocity tracking task in a boost converter driven DC motor system. The controller is a linear controller based on the exact tracking error dynamics passive output feedback (ETEDPOF) controller design methodology including suitable feed-forward controllers.

HeberttSira-Ramirez et al has described in the paper, "On the Robust Control of Buck-Converter DC-Motor Combinations", an active disturbance rejection control and flatness-based control to regulate the response of a dc-to-dc buck power converter affected by unknown, exogenous, time-varying load current demands. Here, PI controllers are also used. A key element in the proposed control for the buck converter-dc motor combination is that even if the control input gain is imprecisely known, the control strategy still provides proper regulation and tracking.

M. Z. MohdTumari et al has described in the paper, "H-infinity with pole placement constraint in LMI region for a buck-converter driven DC motor", an H-infinity synthesis with pole clustering based on LMI region schemes to control the speed of a DC motor. The dynamic system composed of converter/motor is considered in this investigation and derived in the state-space and transfer function forms.

III. METHODOLOGY

In existing method, a hierarchical controller that carries out the angular velocity trajectory tracking task for the dc/dc Buck converter–dc motor system was used. To achieve this, as a variation of i) two independent controllers are designed; one for the dc motor (via differential flatness) and another via the cascade scheme (through the SMC and PI control) for the Buck converter, which are then interconnected in order to work as a whole. Additionally, experimental validation of the proposed hierarchical controller's performance is included, showing how the trajectory tracking task is successfully accomplished, even when abrupt variations of the system parameters appear, so exhibiting the robustness of the controller presented.

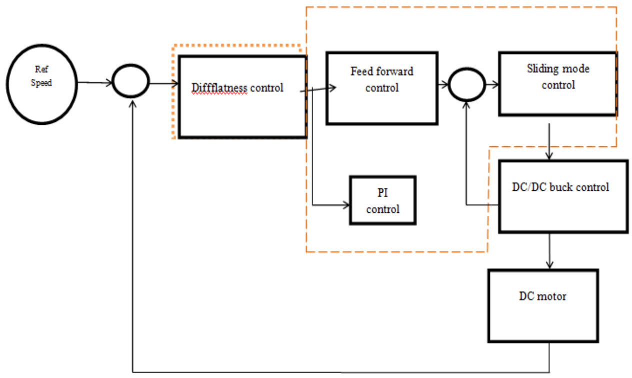

Fig 1: Block Diagram

A. *DIFFERENTIAL FLATNESS CONTROL*

Here, the angular velocity tracking of DC motor is done. That is, the output voltage of DC/DC buck converter is tracked.

B. *SLIDING MODE CONTROL*

Sliding mode control is a non-linear control technique remarkable property of accuracy, robustness and easy implementation. This allows the system to become insensitive to the disturbances.

C. *FEED FORWARD CONTROL*

Feed forward controller can react before the effect of the disturbance shows up in the output. The performance can be greatly improved by using feed forward control.

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The integration of two controllers is defined here. The angular velocity tracked by differential flatness control is given as input to the cascade control in terms of voltage. In cascade control the sliding mode control controls the current loop and the PI controller controls the inner current loop. The desired voltage for buck converter v^* is determined by the voltage ϑ, obtained from controlling the dc motor. This allows the angular velocity tracking for DC/DC buck power converter-DC motor system. The input voltage is applied to the motor according to the task. When the motor attains the speed, the voltage decreases and remains constant. In this system, the integral square error is high and it has low step response.

In proposed system, Ant Colony Algorithm is used. It is a new evolution simulated algorithm. It searches the optimized solution through the evolution process of the group combined by candidate solution. This algorithm adopts positive feed-back mechanism in order to implement intelligent searching and global optimization; meanwhile, it has strong robustness.

D. Description

The ant colony optimization algorithm (ACO) is a probabilistic technique for solving computational problems which can be reduced to find good paths through graphs.

In the natural world, ants (initially) wander randomly, and upon finding food return to their colony while laying down pheromone trails. If other ants find such a path, they are likely not to keep travelling at random, but to instead follow the trail; returning and reinforcing it if they eventually find food.

Over time, however, the pheromone trail starts to evaporate, thus reducing its attractive strength. The more time it takes for an ant to travel down the path and back again, the more time the pheromones have to evaporate. A short path, by comparison, gets marched over more frequently, and thus the pheromone density becomes higher on shorter paths than longer ones. Pheromone evaporation also has the advantage of avoiding the convergence to a locally optimal solution. If there were no evaporation at all, the paths chosen by the first ants would tend to be excessively attractive to the following ones.

Thus, when one ant finds a good (i.e., short) path from the colony to a food source, other ants are more likely to follow that path, and positive feedback eventually leads all the ants following a single path. The idea of the ant colony algorithm is to mimic this behavior with "simulated ants" walking around the graph representing the problem to solve.

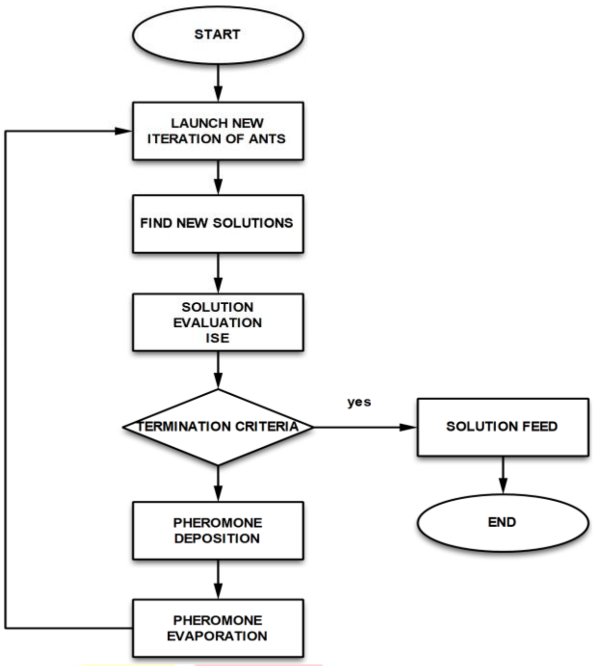

Fig 2 : Flow Chart of ACO Algorithm

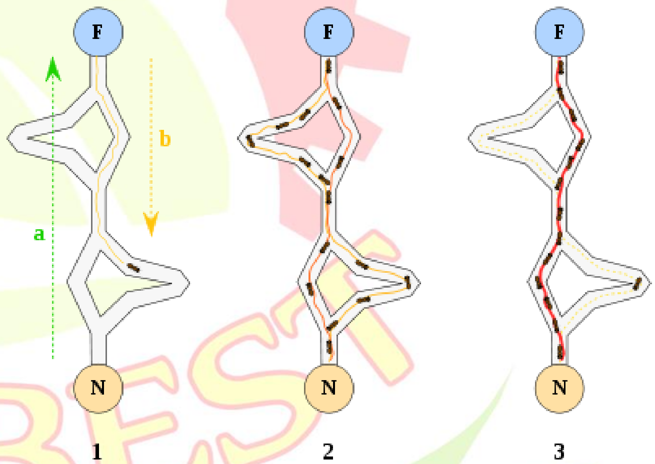

Fig 3: Optimization Process by ACO Algorithm

The original idea comes from observing the exploitation of food resources among ants, in which ant's individually limited cognitive abilities have collectively been able to find the shortest path between a food source and the nest.

1. The first ant finds the food source (F), via any way (a), then returns to the nest (N), leaving behind a trail pheromone (b)

2. Ants indiscriminately follow four possible ways, but the strengthening of the runway makes it more attractive as the shortest route.

3. Ants take the shortest route, long portions of other ways lose their trail pheromones.

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In a series of experiments on a colony of ants with a choice between two unequal length paths leading to a source of food, biologists have observed that ants tended to use the shortest route. A model explaining this behavior is as follows:

1. An ant (called "blitz") runs more or less at random around the colony;
2. If it discovers a food source, it returns more or less directly to the nest, leaving in its path a trail of pheromone;
3. These pheromones are attractive, nearby ants will be inclined to follow, more or less directly, the track;
4. Returning to the colony, these ants will strengthen the route;
5. If there are two routes to reach the same food source then, in a given amount of time, the shorter one will be traveled by more ants than the long route;
6. The short route will be increasingly enhanced, and therefore become more attractive;
7. The long route will eventually disappear because pheromones are volatile;
8. Eventually, all the ants have determined and therefore "chosen" the shortest route.

The basic philosophy of the algorithm involves the movement of a colony of ants through the different states of the problem influenced by two local decision policies, viz., trails and attractiveness. Thereby, each such ant incrementally constructs a solution to the problem. When an ant completes a solution, or during the construction phase, the ant evaluates the solution and modifies the trail value on the components used in its solution. This pheromone information will direct the search of the future ants.

As a very good example, ant colony optimization algorithms have been used to produce near-optimal solutions to the travelling salesman problem. The first ACO algorithm was called the Ant system and it was aimed to solve the travelling salesman problem, in which the goal is to find the shortest round-trip to link a series of cities.

IV. RESULTS

A. SPEED VS. TIME

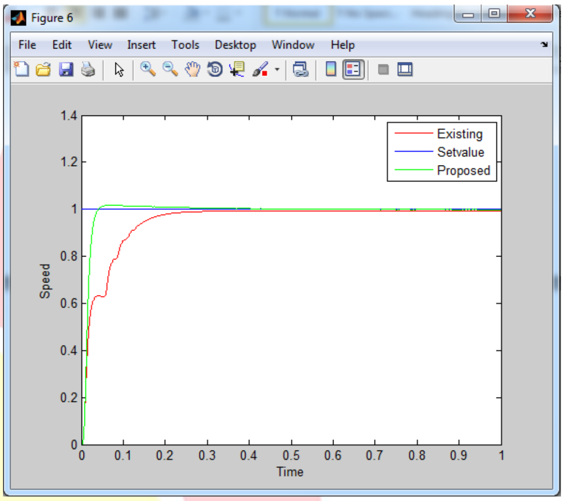

Fig 4 :Comparison result of existing and proposed system

B. CURRENT VS TIME

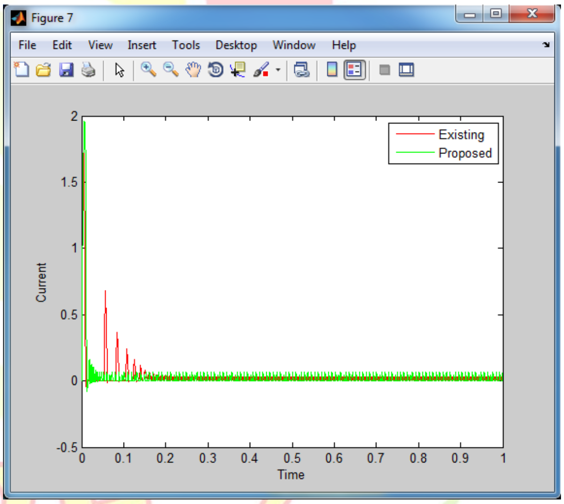

Fig 5:Comparison result of current

C. VOLTAGE VS TIME

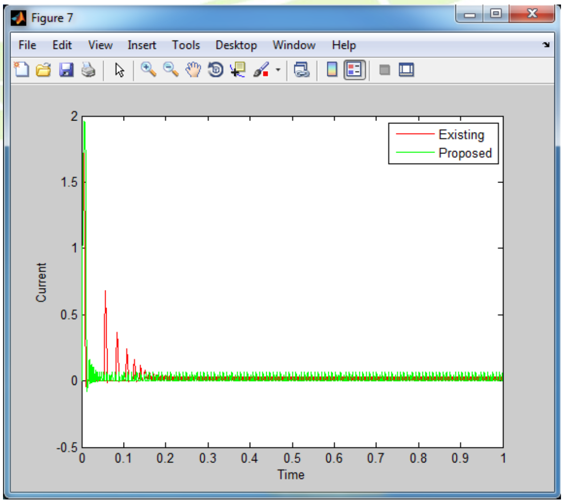

Fig 6: Comparison result of voltage

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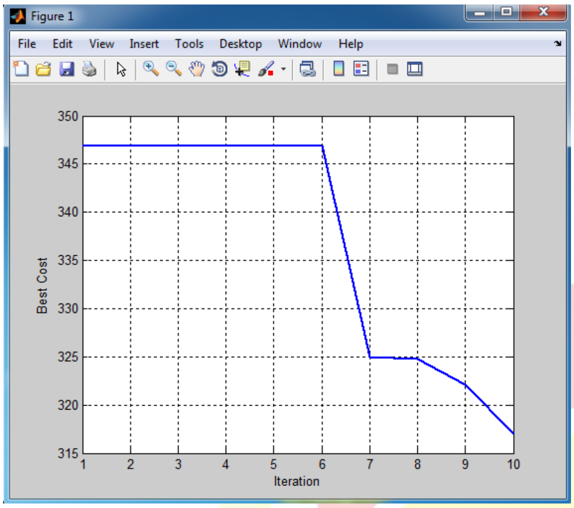

Fig 7 : ACO optimization for finding optimal gain value

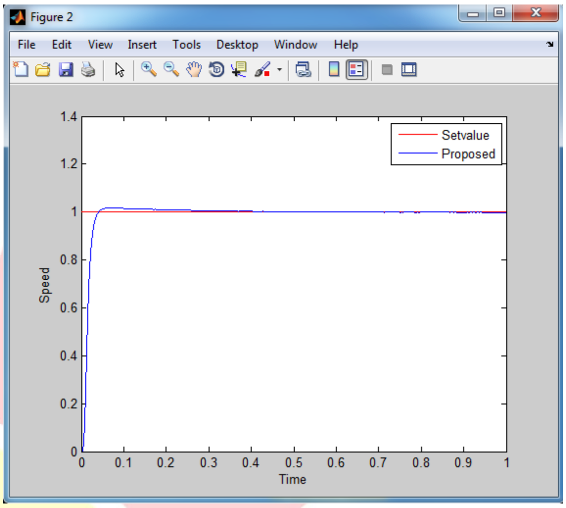

Fig 10: Proposed step response

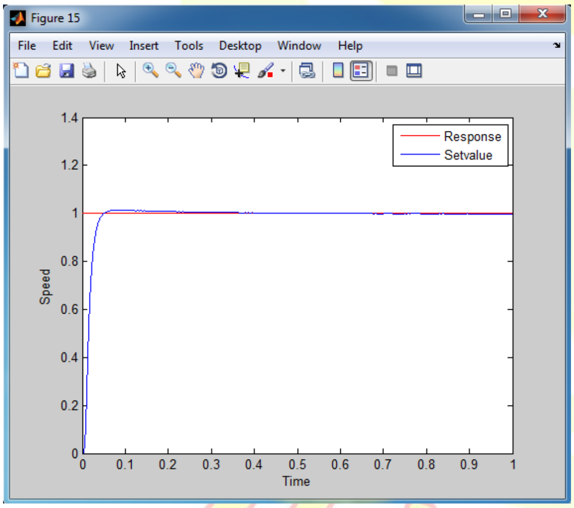

Fig 8:Speed response of proposed system

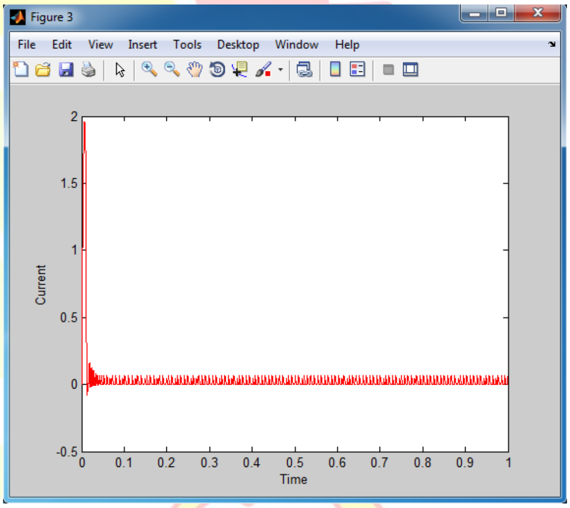

Fig 11:Current level.initially high value current due to torque

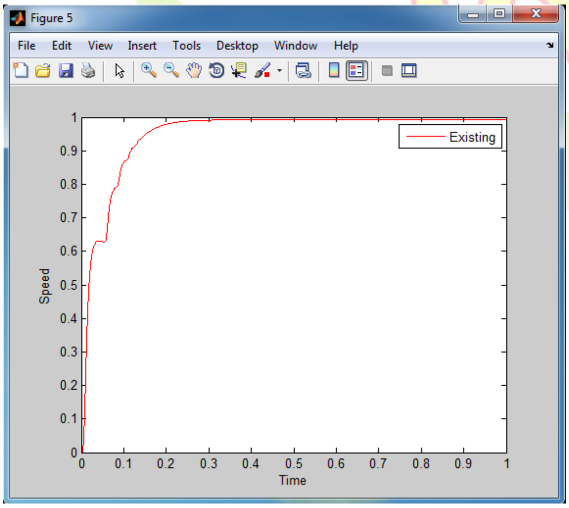

Fig 9: Existing performance with respect to time

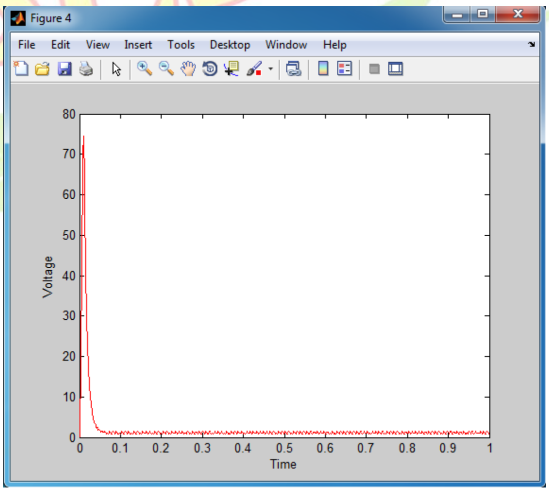

Fig 12: Voltage level. Initially controller has high error and produce high level voltage

Table 1 Performance Analysis

Sl.No	***Parameters***	***Existing***	***Proposed***
1	Rise Time	0.1070	0.0183
2	Settling Time	0.1857	0.0346
3	Settling Min	0.8933	0.8989
4	Settling Max	0.9924	1.0171
5	Overshoot	0.0010	1.8419
6	Undershoot	0	0
7	Peak	0.9924	1.0171
8	Peak Time	0.6983	0.0660

V. Conclusion

In this project based on Ant Colony Optimization technique.ACO performs better against other global optimization techniques, retains memory of entire colony instead of previous generation only, less affected by poor initial solutions and can be used in dynamic applications and has been applied to a wide variety of applications. It is also a good choice for constrained discrete problems. Theoretical analysis is difficult; due to sequence of random decision, research is experimental rather than theoretical, convergence is guaranteed, but time to convergence is uncertain. In NP-hard problems, need high-quality solutions quickly-focus on quality of solutions and in dynamic network routing problems, need solutions for changing conditions.

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Authors Biography

Prathyusha.P was born on 17th July 1992.She did her Bachelor of Engineering in the department of Electrical and Electronics Engineering in Ponjesly College of Engineering. Currently She is doing her Master of Engineering in Applied Electronics in Mar Ephraem College of Engineering and Technology. She has attended a seminar on smart grid at Ponjesly College of Engineering. She has attended workshop on Matlab at St.Xaviers Catholic College of Engineering. Her area of interest includes optimization techniques like Ant Colony Algorithm and all.

Babin T Praise was born on 4th September 1987. He did his Bachelor of Engineering in ECE in Noorul Islam College of Engineering. He has completed his Master of Technology in Remote Sensing in Anna University Chennai. Currently he is doing research in medical image processing and mainly foccused on satellite image processing. He is a Permanent member of IET.

Suresh.V did his Bachelor of Engineering in the department of Electrical and Electro--nics Engineering in Noorul Islam College of Engineering and M.E in Mohammed Sathak college of engineering. He currently en--gaged himself in E-Yantra Robotics lab funded by MHRD and mainly concentrating on power electronics.