Manifold Robotic lamps with Automatic illumination system

***Abstract*—An automatic illumination system using 3-DOF robotic lamps and a laser scanner is proposed in this paper. The 3-DOF robotic lamp, which is designed with a spherical parallel mechanism, has a tilting motion to track a person and zoom-in and zoom-out motions to control the light intensity. The positions of people are detected by a laser scanner, and the Kalman filter and a data association algorithm are applied in order to track the positions of people accurately. We demonstrate experimentally that three robotic lamps mounted on the ceiling illuminate three people in- dependently and control the intensity of the light according to the distance between a person and the robotic lamp.**

I. INTRODUCTION

THE trend in the illumination market has changed from fluorescent and incandescent lamps to LED lamps. Because an LED lamp needs low power and is brighter than an incandescent lamp, it is widely used in TVs, cars, traffic lights, and so on. In addition, since an LED is small and can express various colors, an LED lighting apparatus used in an interior design can be developed to suit a wide variety of styles.

There are many sensors such as a passive infrared (PIR) sensor, a laser scanner, an ultrasonic sensor, a position sensing device, and so on. A PIR sensor can distinguish humans from objects because it gauges the temperature change of the human body. A laser scanner can measure the distance between the sensor and objects in 2-D space 10–60 times per second using an infrared ray and it is not affected by light. Therefore, a laser scanner is suited to the detection of moving objects. However, even though a laser scanner can obtain sensor data accurately and quickly, it has difficulty in distinguishing humans from objects. To solve this problem, the use of object tracking algorithms is required.

In this paper, we propose a ceiling-mounted 3-DOF robotic lamp to realize an automatic lighting system using multiple robotic lamps and a laser scanner. This robot tracks the position of one person inside a room with the aid of a PIR sensor. When the PIR detects the humans, the light source on the one side of the room will rotate at 180 degree continuously till the human is present on one side of the room. This continues on the other side of the room in a similar manner.

In the experiment, three robotic lamps automatically track and illuminate three persons independently who were detected by a laser scanner. The performance of the automatic lighting system was verified through several experiments.

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II. DESIGN OF ROBOTIC LAMP

A. Three- DOF(Degree Of Freedom)

Fig. 1 shows the side view of the robotic lamp and its sub- systems including a lamp module, parallel linkage, and a base frame with actuators. Two guide linkages in the parallel linkage create two tilting motions of the lamp to track a person. The tilting motion is created by two guide linkages operated by two motors, and the zoom-in and zoom-out motions are created by a bevel gear set and a screw transmission operated by one motor. motor was chosen by considering that the motion speed of a person in daily life is less than 1 m/s. The maximum speed of the tilting motions is 1.3 rad/s. Therefore, if the robotic lamp is installed at a position higher than 1 m, it does not have the speed problem. The maximum torque of motor was selected so that it is able to cope with an expected dynamic motion of the robotic lamp. The motor for the zoom-in and zoom-out motions has 1:71 gear ratio, 3.1 kgf·cm torque, and 91 r/min speed.

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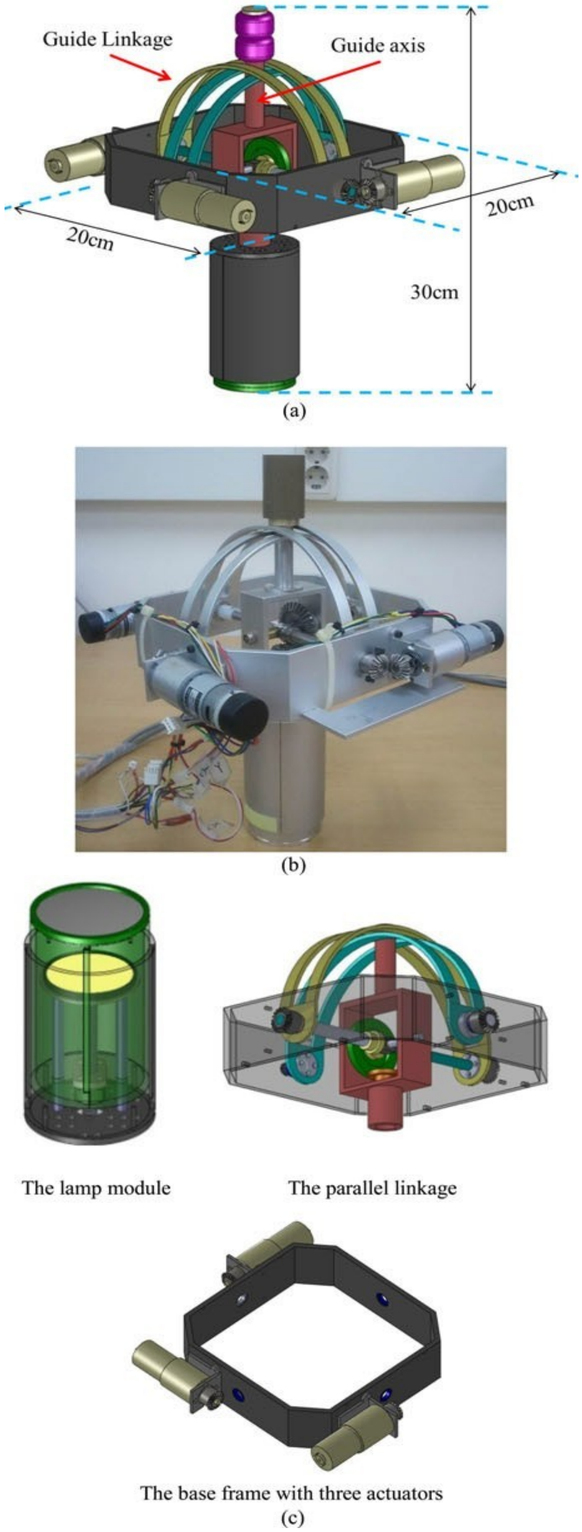

Fig. 1. Three-DOF robotic lamp. (a) CAD model. (b) Real prototype. (c) Parts of the robotic lamp.

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B. Linkage Design

There are several features in the robotic lamp. Using the spherical-type parallel mechanism, the two actuators are used to create the tilting motion and one motor is used for the zoom in-and-out motions. It is also noted that the new design shown in Fig.1 has better mechanical strength as compared with the previous design shown in Fig. 2. The distance between the lamp module and the base frame in the new version of Fig. 3 is shorter than the distance in the previous version. Thus, the inertia of the lamp is smaller. The guide linkages of the previous version cannot be thinner because they must sustain the load of the heavy lamp module. However, the guide linkage of the new version in Fig.3 can be designed to be thinner. This is because the guide linkages of the new version are located in the upper hemisphere instead of in the lower hemisphere. the guide linkage does not support as large of a load as the design in Fig. 2.

Thus, the new version of the robotic lamp has a strong ad- vantage because of its compact design and high payload.

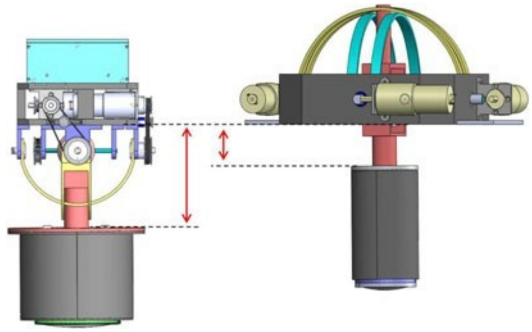

Fig 3.Comparison of two 3-DOF robotic lamps.

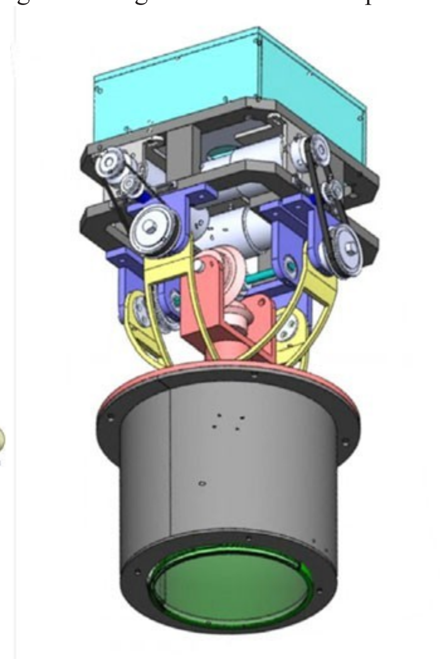

Fig2. Previvous version of 3-DOF robotic lamp

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III. AUTOMATIC ILLUMINATION SYSTEM

A. Lighting System:

In Fig. 4, the autonomous illumination system is comprised of three robotic lamps, one laser scanner, six motion control boards, and one computer to manage the whole system. Each robotic lamp tracks and lightens each person in the scanning area. More than three robotic lamps and persons in the workspace can be considered in the same way.

A computer, a laser scanner, and the main motion control board communicate with each other through RS-232, and the three robotic lamps communicate with ECAN as shown in Fig. 5. A laser scanner is employed to detect the positions of people.The motion control board is designed to control at most two motors simultaneously. Therefore, the three desired angles of one robotic lamp are controlled by two motion control boards.

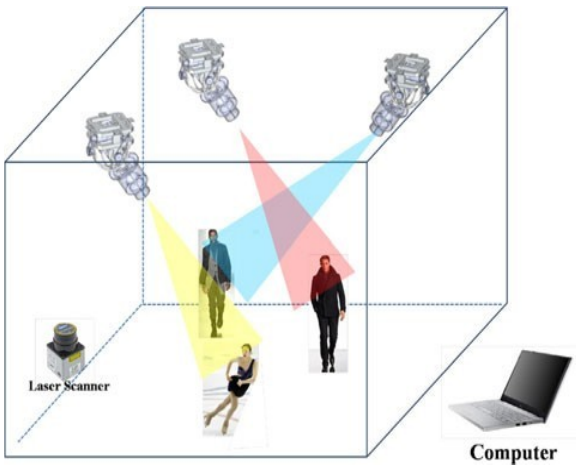

Fig. 4. Automatic lighting system.

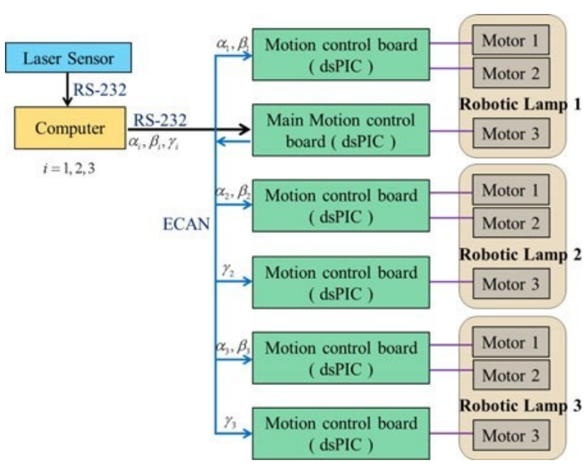

Fig. 5. Signal block diagram of the lighting system.

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B. Laser Scanner

In this paper, a range-finder type of laser scanner (URG-04LX, Hokuyo Automatic) is used. The light source of the sensor is an infrared laser with a wavelength of 785 nm, a scanning direction that is counterclockwise, at a scanning frequency of ten scans per second. The detectable scanning area is 240 degrees, and one infrared ray scans every 0.3515625 degrees in the scanning range.

In the test room, a laser scanner is installed 0.9 m above the ground, so most people are detected at a height between the hip and the waist. When a laser scanner scans the hip or the waist of the human body, usually two arms are also detected. Because the radius of an arm is much smaller than that of the waist or the hip, it is easy to recognize the arms around the human body. When the position of a human is calculated, the positions of the arms are not considered.

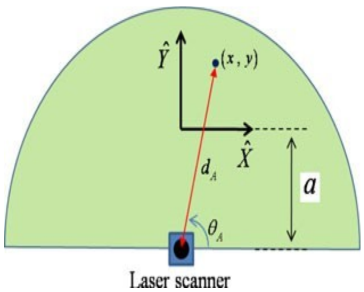

Fig. 6. Coordinate system in the scanning area.

Fig. 6 shows the coordinate system in the scanning area of Fig. 4. d_A is the distance between a human and the laser scanner, and θ_A is the angle between a human and the laser scanner. The position (x, y) of the human inside the scanning area can be However, because a laser scanner returns the position of people

as one laser ray rotates counterclockwise and measures the distance and the angle of a person, a blind spot may exist, as shown in Fig. 7.

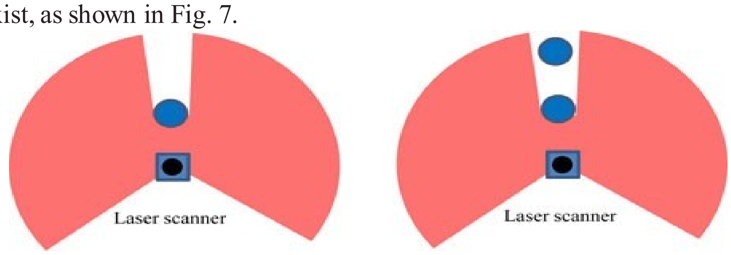

Fig. 7. Detectable area and blind spots of a laser scanner.

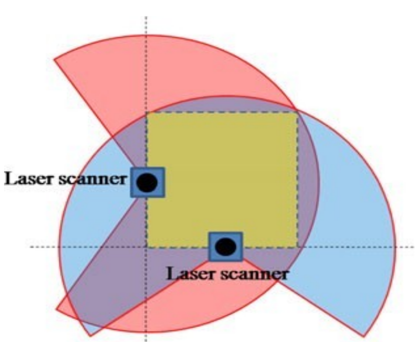

Fig. 8. Overlapped detectable area when two laser scanners are used.

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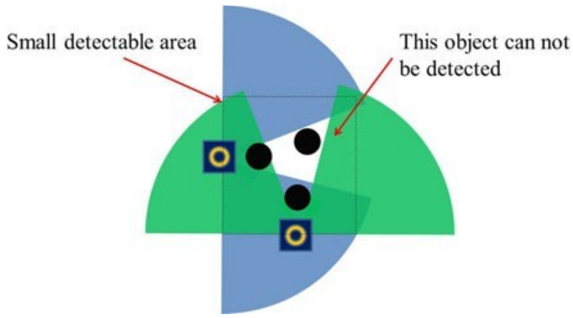

Fig. 9. Blind region.

In this case, even though there are two objects, since the front object hides the rear one, the laser scanner recognizes only the front object instead of both objects. Therefore, one way to resolve the blind spot problem is by using more than two laser scanners as shown in Fig. 8.

IV. HUMAN TRACKING ALGORITHM

A. Data Association:

A laser scanner detects the positions of objects in the scanning area every 100 ms, but it cannot distinguish the identity of an object. Therefore, the position of an object should be measured and saved by the computer for every scan in order to judge whether or not the object has moved

Fig. 10 illustrates measurement prediction in a blind spot. When the human enters the blind spot, the measurement vanishes, so only the position of the measurement is predicted. As the scanning time elapses, the detectable region of the measurement prediction increases, such that after the measurement passes the blind spot, the probability of redetection is high. Fig. 11 shows the algorithm for these procedures.

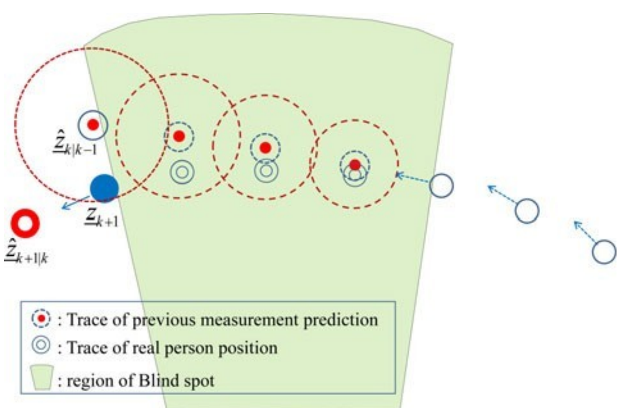

Fig10: Measurement prediction in a blind spot

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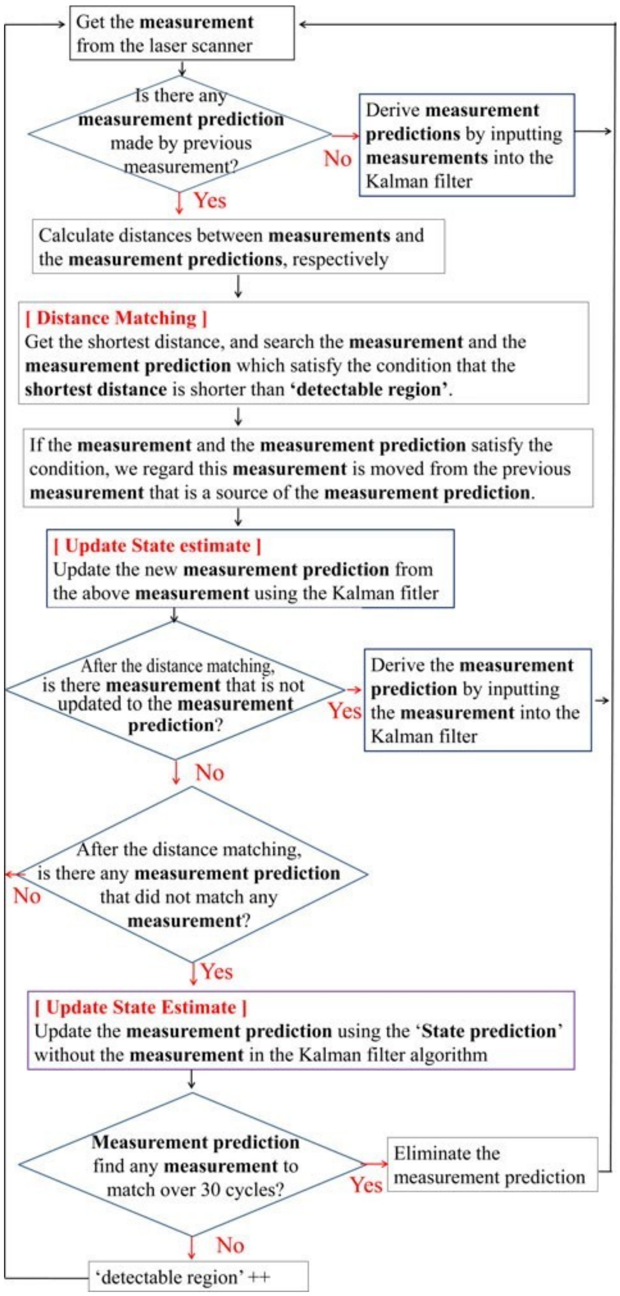

Fig. 11. Algorithm of the automatic lighting system.

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V. EXPERIMENT

A. Performance of Manifold Robotic Lamps:

Fig. 12 shows the performance of the multiple robotic lamps for different numbers of people in the scanning area. If there is one person in the room, all of the robotic lamps illuminate the person, and if there are two people in the scanning area, only two robotic lamps illuminate the people assigned to each lamp, and the other robotic lamp stops. If there are more than two people in the scanning area, we control multiple robotic lamps so that three individual lamps track and light each person. That is, the multiple robotic lamps continuously track and illuminate the first three people in the scanning area. Whenever a person enters the scanning area, we assign a number in order to track the person, and the robotic lamps have different priorities. When more than two people are in the area, a robotic lamp that has the first priority is assigned to the first entered person. The assignment process depends on the priorities of the robotic lamp and the assigned number of the people. If one person leaves the area, the assigned lamp stops tracking and waits or finds a person who has the lowest number and does not have an assigned robotic lamp.

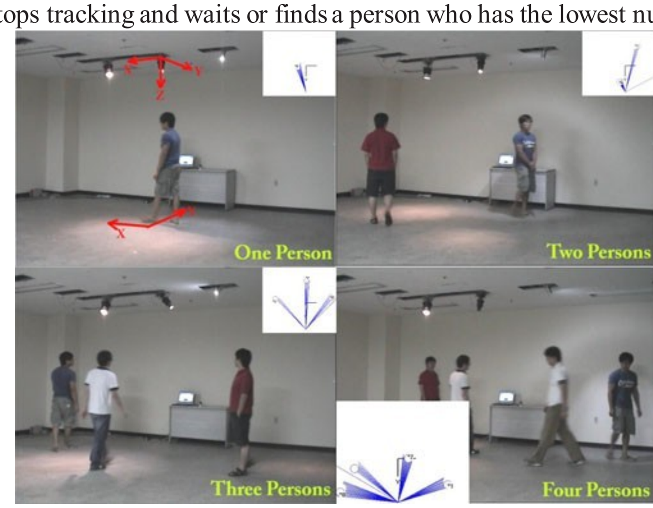

Fig. 12. Performance according to the number of people.

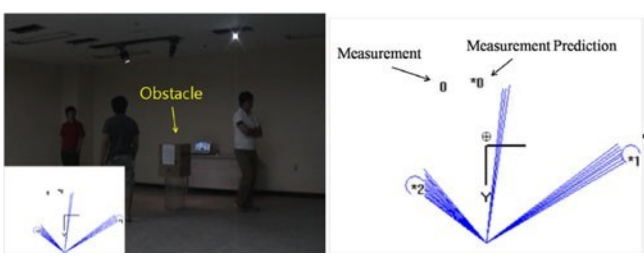

Fig.13 . Performance with an obstacle.

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VIII. CONCLUSION

An autonomous lighting system using multiple robotic lamps was designed to track and illuminate people independently. The advantages of this robotic lamp are as follows.

1) The mechanism is compact and easy to install on the ceiling.
2) Two tilting motions and a zooming function can be realized within one parallel module.
3) By adapting a counterbalancing design, the robotic lamp can control the heavy lamp with less input power.
4) The zooming function of this robotic lamp is unique in the sense that the distance between the lamp and a person is automatically controlled, and the intensity of the light can be controlled accordingly.

Through experimentation, we demonstrated that a laser scanner could precisely measure the positions of moving people. This multiple robotic lamp system can be employed for an automatic stage lighting system. Future work will involve using multiple sensors to resolve the blind spot problem and using more sophisticated estimation algorithms to enhance the success rate.

IX. ACKNOWLEDGMENTS

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X. REFERENCES

[1] Passive Infra-Red Motion Sensor (NaPiOn), Panasonic Inc. (2013). [Online]. Available: http://pewa.panasonic.com/components/built-in- sensors/passive-infrared-sensors/napio

[2] G. Fu, P. Corradi, A. Menciassi, and P. Dario, "An integrated triangulation laser scanner for obstacle detection of miniature mobile robots in indoor environment," *IEEE/ASME Trans. Mechatronics*, vol. 16, no. 4, pp. 778–783, Aug. 2011.

[3] E. J. Jung, J. H. Lee, B.-J. Yi, and S. Yuta, "Marathoner tracking algorithms for a high speed mobile robot," in *Proc. IEEE RSJ Int. Conf. Intell. Robots Syst.*, San Francisco, CA, USA, Sep. 2011, pp. 3595–3600.

[4] Y. S. Lee, D. K. Yoon, J. T. Seo, and B.-J. Yi, "Automatic tracking of human-body using a 3 DOF robotic lamp," in *Proc. IEEE Int. Conf. Mechatronics Automat.*, Beijing, China, Aug. 2011, pp. 470–476.

[5] X. Kong and C. M. Gosselin, "Type synthesis of 3-DOF spherical parallel manipulators," *Int. J. Robot. Res.*, vol. 23, no. 3, pp. 237–245, 2004.

AUTHOR PROFIE:

[1] B.Vennela Pursuing Master of Technology (Embedded Systems) from Jawaharlal Nehru Technological University (JNTUH). Presently working as TEQIP Assistant in the department of ECE in Anurag Engineering College (AEC), Ananthagiri (V), Kodad (M), Nalgonda (Dt.), Andhra Pradesh, India.

[2] M.Basha received Master of Technology (Digital Electronics & Communication Systems) from Jawaharlal Nehru Technological University Anathapur (JNTU-A). Presently working as Associate Professor in ECE Department in Anurag Engineering College (AEC), Ananthagiri (V), Kodad (M), Nalgonda (Dt.), Andhra Pradesh, India.

[3] Dr.M.V.Siva Prasad awarded Ph.D from Nagarjuna University, Guntur, and received M.Tech. [SE] from VTU, Belgaum and B.E. [CSE] from Gulbarga University, presently working as principal in Anurag Engineering College (AEC), Ananthagiri (V), Kodad (M), Nalgonda (Dt.), Andhra Pradesh, India.

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