International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-9 Issue-9, July 2020

Modeling, Fabrication & Control of an Articulated Robotic Arm

G Krishna Teja, K S Sandesh, K Saichand, V Kalyan

Abstract*: Modeling and Fabrication of robotic systems and their control for pick &place and maintenance tasks is highly complex activity involving coordination of various sub-systems. The entire design has four important modules: (i) CAD Modeling (ii) Control System Design (iii) Machine Vision and Image Processing, (iv) Hardware Development and Testing. The five-axis articulated manipulator equipped with a vision camera in eye-to-hand configuration is designed for performing the pick and place operations of the defected tiles in a systematic manner. Dynamics of manipulator is required for design of model-based controllers. Interactive programs are developed in Matlab for kinematics and dynamics. Three-dimensional manipulator assembly configuration is modeled in Pro-E software. Motion analysis is conducted in Arduino software in order to compare the results obtained from the classical kinematics. The test set-up is developed using vision camera and microcontroller platform to guide the robot joint servos so as to perform defected object replacement activity. Presences of the coordinate of the region are indicated with the use of image-processing operations.

***Keywords*: Arduino software, Motion analysis, Image Processing.**

I. INTRODUCTION

Robotics, automation and remote handling technology plays an important role in almost all facts of pick and place task. The recent advancements in this improving area have been due to various necessities unique to industry such as starting from reducing the manpower during operation, technologies requirement to facilitate remote pick and drop at inaccessible areas of industrial plants or to facilitate remote repair/refurnish of operating plants. Remote handling/robotic tool design is essential in the areas of pick and place tasks. Advancements in this technology, by way of CAD modeling, control/automation, advance control and various modules coupled with experimental works are crucial applications in pick and place of objects or material.

With the tenacious need for increased quality, productivity and automation, the world is tuning more and more towards various autonomous and semi-autonomous robots which finds a wide array of applications.

Revised Manuscript Received on July 30, 2020.

* Correspondence Author

G Krishna Teja*, Assistant Professor, Department of Mechanical Engineering, Anurag University, Hyderabad, India. E-mail: gkrishnatejamech@cvsr.ac.in.

K S Sandesh, Department of Mechanical Engineering, Anurag University, Hyderabad, India.

K Sai Chand, Department of Mechanical Engineering, Anurag University, Hyderabad, India.

V Kalyan Sagar, Department of Mechanical Engineering, Anurag University, Hyderabad, India.

A common attribute of such described applications is that robot needs to operate in inhuman, unstructured environment where human intervention is risky. Motion control, trajectories paths for robots in unstructured environments face significant challenges due to various uncertainties in environment. So a complete study and analysis of CAD modeling for simulation, fabricationand control of various sensor systems such as vision is essentially needed.

II. PROBLEM STATEMENT

Based on the requirements in industry, there is a need to design a low-cost robotic platform which is to be operated remotely through the gripper and control data. This should facilitate in avoiding human involvement in heavy environments.

Design of such a robotic platform requires several consideration including trajectory tracking and force control during replacement events. In such tasks, redundant robots are advantageous; however their control issues do not permit their usage everywhere.

In this regard, design and development of a serial articulated multi-link mechanism is a necessary task. As in conventional robots, the linkage needs joint control to guide the end effectors. Further, it also needs a kind of remote control of joint motions.

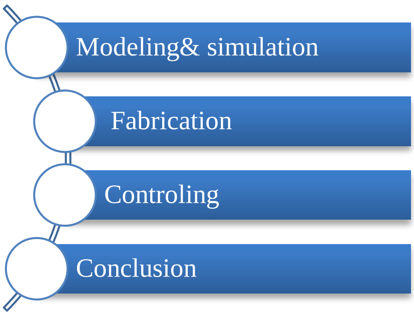
III. METHODOLOGY

This chapter highlighted the important research activities on robotic manipulator working in hostile environments in terms of their applications, configurations, CAD modeling, fabrication, remote controlling abilities, vision sensing and image processing. Modeling of manipulators has been attempted by several researchers for specific tasks. Advanced application of remote control and vision sensing has been found be the recent research areas in controlling the robots accurately. In this regard the software tools the Pro-E for modeling, Arduino for controlling and other motion simulator are found to be very much useful.

Following issues are found to be the open areas in further study.

I. Modeling of an articulated arm using 3D modeling software for simulation.
II. Fabrication of validated model of articulated arm.
III. Choosing required power sources, actuators and control setup.

Development of a control algorithm for performing required tasks.



Manipulator considered for the tile replacement activities is a conventional articulated 5-axis robotic arm, because the application requires an operation similar to pick and place where the end-effector orientations plays a limited role and control task become easier. Further the dynamics of manipulator can also be simplified by treating the wrist of the manipulator to be in rigid posture. It has a 3-axis arm and 2 degree of freedom wrist. At the end of wrist, an end-effector (2-finger gripper) is connected. Each link is actuated by its joint servomotor as per requirement. This configuration is selected due to its well-known kinematics and dynamics. Further, the manipulability can be enhanced by mounting it over a mobile base and camera.

IV. MODELING & SIMULATION

Fabrication and testing of the articulated 5 DOF manipulator for replacements activities. It gives elaborate description of robot of fabrications details, and electronic and sensor interfaces. Initially few preliminary design considerations have been taken as per the feasibility and ease of the design and further modified to suits the present requirement as per available specification.

Base:

The base with Fig of the manipulator is the most crucial part as it has to take the whole load of the arm, thus attention has been taken to make it practically strong and sturdy. Further the material to be fabricated has been chosen to be strong enough so that it wouldn't deform under load and will be ease to withstand all shock and vibrations. Figure 1 shows the projections along with isometric view of the base.

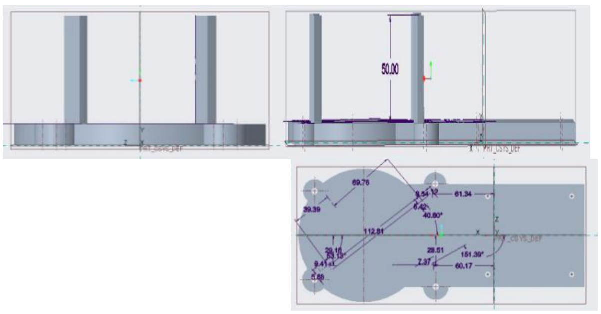
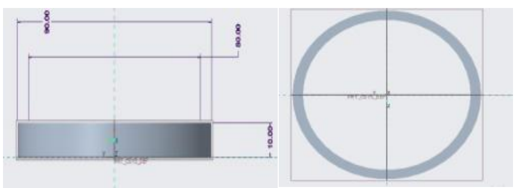


Fig 1

Mounting plate:

Mounting plate is use for the holding of bearing between them for the rotation of the manipulator.



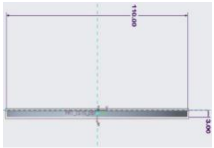


Fig 2

Bearing:

The bearing is used for the rotation of the robot the bearing series is used for the robot is S62202 which mounted between the plates.

Lower Arm:

Like the base the body Figure 3 shows the dimensional views of the lower arm and care has been taken to make it very strong and robust as such it houses the servo motor to drive the link. The lower arm is driven by a servo at the joint connecting the base with it. The servo motors often have shafts with geared pinions. So it is desirable to generate.

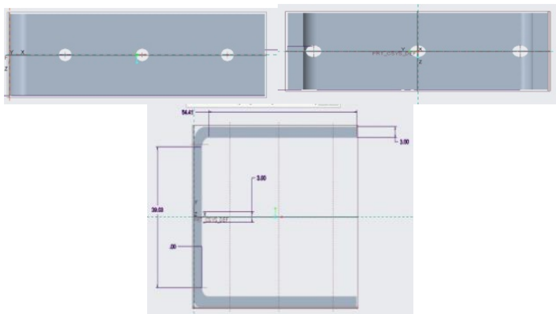


Fig 3

Upper Arm:

The upper arm which is the link 2 is shown in Figure 4.6. It is designed to be somewhat lighter in weight from that of base and body. All this has been joined and interconnected with the servo motor directly at the joints.

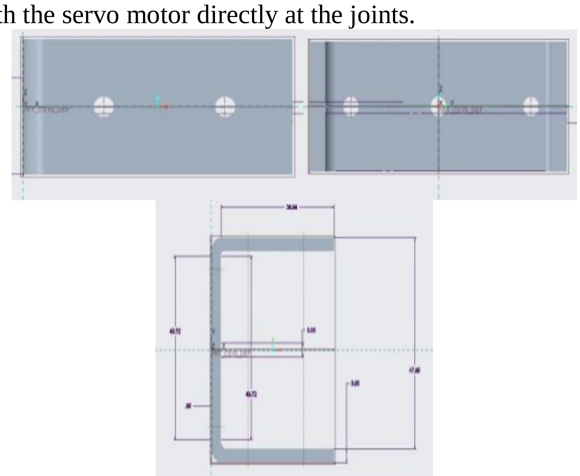


Fig 4

End-Effector Casing:

The casing or hand for the end-effectors is shown in Figure 5 is the last link of the manipulator. The gripper for pick and place has been has been secured on this link. Here, a servo motor will be placed to provide a roll motion to the gripper. The pitching motion is given by the servo placed at the beginning of the casing. The servo motor is placed by the design which are holding of the motors and which at the end of the motor gripper is connected.

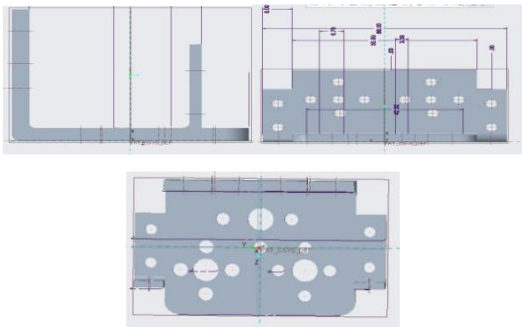


Fig 5

End-effectors:

A two Finger gripper has been used as an end-effectors in finger 6. It works on the principle of parallelogram mechanism, which gives the fingers a better gripping capacity as they move parallel to each other.

Currently the gripper can take a load of 300 grams but the weight can be further extended with the use of high torque motors. The gripper has maximum opening of 5.5cms. The gripper or end-effectors is employed in the present task is meant only for the uncontrolled force gripping action. Therefore, a readymade

3

light weight gripper with fingers actuated by a micro servo may be directly employed at the end-effectors casing.

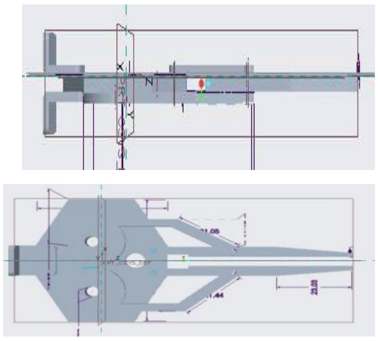


Fig 6

The Figure 7 shows the assembly model of the all five components with gripper.

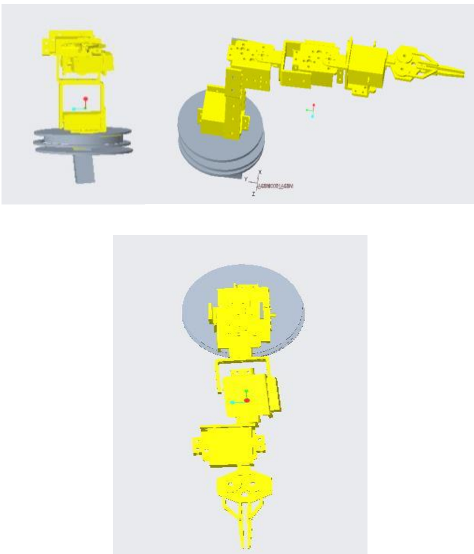
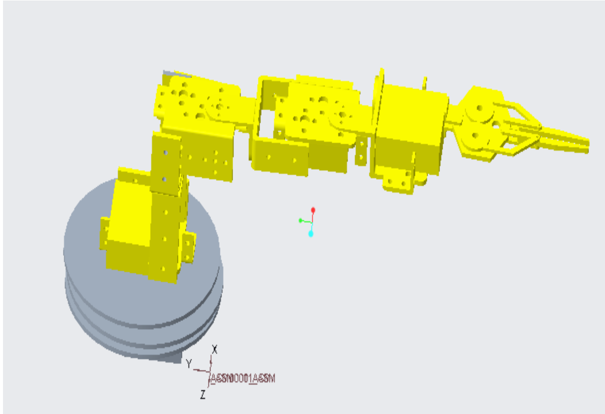


Fig 7 - 3D Model of robot



Assembly & Simulation Model in PRO-E

The assembly-model can be used for performing the kinematic simulations and static stress analysis to understand further.

V. FABRICATION OF THE ROBOTIC ARM

Designing a robotic system from the scratch is much a time consuming and lengthy process. Thus, various existing standard models have been studied in detail and researched before starting the fabrication work. Care has been taken to understand the problem concept and how feasible design has to be made for a better solution. Fabrication involved a lot of machining process, which was carried out in the institute workshop for about a year. All the primary processes involved in the fabrication of the robot has been explained in this section.

Table I Manipulator summary

Parameters	Description
No of joints	5
No of DOF	5
Range of Motion	Wrist Pitch -110^0 - $+110^0$
	Wrist Roll -90^0 - $+90^0$
	Elbow -90^0-$+90^0$ Shoulder -90^0-$+90^0$
Locomotion	Articulated Links
AC	6 DC servos motion
Weight	2.0 kg
Dimensions	Base Radius – 110 mm Lower Arm – 90mm Upper Arm – 90mm End Effector – 110mm
Gripper	2 finger grippers with high strength aluminum
Payload	0.3 kg

Machining of the Robotic Arm

Various parts of the robotic arm witness forces at different direction and magnitude. Thus, suitable materials have been selected to fabricate each part. Parts such as shoulder arm, elbow arm end-effector casing etc. However, for the base part the wood has been selected because of easy machining and sturdy stability. Figure 7 shows the fabricated prototype prepared.

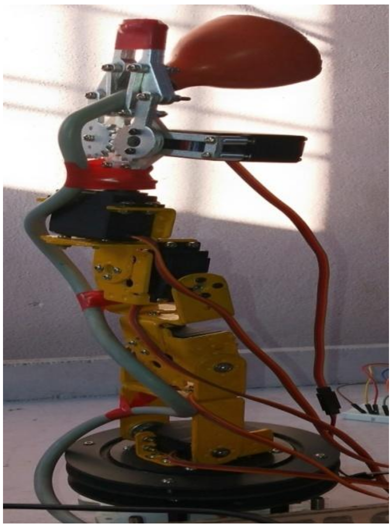


Fig 8

VI. CONTROLLING

Control of the robotic arm is with the software and the micro controller Arduino UNO R3 with this we can control the Arm and used friendly for application of pick and place we have created the software which we can control manually (Lead through program) and feed into program generate it is the program generate for the pick and place as show below,

```
*/
#include <Wire.h>
#define servo1  (16>>1)
#define servo2  (18>>1)
#define UART_BAUD_RATE  115200
#define LED 13
#define SERIAL_BUFFER_SIZE  256
void I2C_SERVOSET(unsigned char
servo_num,unsignedintservo_pos);
void I2C_SERVOREVERSE(unsigned char
servo_num,unsigned char servo_dir);
void I2C_SERVOOFFSET(unsigned char servo_num,int
value);
void I2C_SERVOSPEED(unsigned char value);
void I2C_SERVONUTRALSET(unsigned char
servo_num,unsignedintservo_pos);
void I2C_SERVOMIN(unsigned char
servo_num,unsignedintservo_pos);
void I2C_SERVOMAX(unsigned char
servo_num,unsignedintservo_pos);
char I2C_SERVOEND(void);
int I2C_SERVOGET(intservo_num);
int I2C_SERVOGETOFFSET(intservo_num);
voidCheckEndMovement(void);
voidPCControlledCode(void);
voidUserCode(void);
voidLEDToggle(void);
volatileintcnt,c,servoval;
volatile char state,servobuf[36],bytecnt;
int interval=100;
unsigned long previousMillis=0;
unsigned long currentMillis = millis();
charrunCode =0;  //1 for PC controlled, 0 for user controlled
charLEDState=0;
#define State_Start  0
#define State_Command  1
#define State_Servoposition  2
#define State_Speed  3
#define State_Servomin  4
#define State_Servomax  5
#define State_Servooffset  6
#define State_Servoreverse  7
#define State_Servonutral  8
#define State_ReadOffsets  9
void setup()
{
cnt=0;
inti;
unsignedint x;
char buffer[10],tmp,tmp1;
float range;
Serial.begin(UART_BAUD_RATE);
Serial.write('S');
Serial.write('r');
pinMode(13, OUTPUT);
pinMode(2, OUTPUT);
pinMode(8, INPUT);
digitalWrite(8,1);
delay(500);
sei();
Wire.begin();
  TWSR = 3; // no prescaler
  TWBR = 18;  //Set I2C speed lower to suite I2C Servo
controller
pinMode(2,OUTPUT);
digitalWrite(2,HIGH);
delay(500);
state=State_Start;

if (digitalRead(8))
  {
runCode=1;
  }

else
```

5

```
 {
runCode=0;
  }
}

void loop()
{
if (runCode ==1)
  {
PCControlledCode();
  }
else
  {
UserCode();
LEDToggle();
  }
}
voidPCControlledCode(void)
{
currentMillis = millis();
if(Serial.available()>0)
```

```
 {
  c=Serial.read();
previousMillis = currentMillis;
if(state==State_Start)
   {
if(c==170)
state=State_Command;
   }
else if(state==State_Servoposition)
   {
servobuf[bytecnt]=c;
bytecnt++;
if(bytecnt==36)
     {
for(inti=1;i<19;i++)
       {
servoval=servobuf[(i*2)-1]<<7;
servoval=servoval+servobuf[(i*2)-2];
         I2C_SERVOSET(i,servoval);
       }
bytecnt=0;
state=State_Start;
Serial.write('r');
CheckEndMovement();
previousMillis = currentMillis;
     }
   }
else if(state==State_Speed)
   {
     I2C_SERVOSPEED(c);
state=State_Start;
Serial.write("rs");
CheckEndMovement();
   }
void ServoSetAll(unsigned int Servo1, unsigned int Servo2, unsigned int Servo3, unsigned int Servo4, unsigned int Servo5, unsigned int Servo6, unsigned int Servo7, unsigned int Servo8, unsigned int Servo9, unsigned int Servo10, unsigned int Servo11, unsigned int Servo12, unsigned int Servo13, unsigned int Servo14, unsigned int Servo15, unsigned int Servo16, unsigned int Servo17, unsigned int Servo18)
{
if (Servo1 >= 500) {I2C_SERVOSET(1,Servo1);}
if (Servo2 >= 500) {I2C_SERVOSET(2,Servo2);}
if (Servo3 >= 500) {I2C_SERVOSET(3,Servo3);}
if (Servo4 >= 500) {I2C_SERVOSET(4,Servo4);}
if (Servo5 >= 500) {I2C_SERVOSET(5,Servo5);}
if (Servo6 > 500) {I2C_SERVOSET(6,Servo6);}
if (Servo7 >= 500) {I2C_SERVOSET(7,Servo7);}
if (Servo8 >= 500) {I2C_SERVOSET(8,Servo8);}
if (Servo9 >= 500) {I2C_SERVOSET(9,Servo9);}
if (Servo10 >= 500) {I2C_SERVOSET(10,Servo10);}
if (Servo11 >= 500) {I2C_SERVOSET(11,Servo11);}
if (Servo12 >= 500) {I2C_SERVOSET(12,Servo12);}
if (Servo13 >= 500) {I2C_SERVOSET(13,Servo13);}
if (Servo14 >= 500) {I2C_SERVOSET(14,Servo14);}
if (Servo15 >= 500) {I2C_SERVOSET(15,Servo15);}
if (Servo16 >= 500) {I2C_SERVOSET(16,Servo16);}
if (Servo17 >= 500) {I2C_SERVOSET(17,Servo17);}
if (Servo18 >= 500) {I2C_SERVOSET(18,Servo18);}
while (!I2C_SERVOEND())
 {
delay(1);
 }
LEDToggle();
}
voidLEDToggle(void)
{
if (LEDState == 0)
LEDState = 1;
Else
```

Comments: Program stated in the software conversion as shown in below.

0	SPEED 70
1	FUNCTION 1 - Ctrl+Up
2	SERVO: 1362 1266 2153 991 2308 1590 X X X X X X X X X X X X
3	SERVO: 1973 1195 1901 560 2416 524 X X X X X X X X X X X X
4	SERVO: 1973 1195 1901 560 2416 1290 X X X X X X X X X X X X
5	SERVO: 740 1506 2201 1111 2404 1290 X X X X X X X X X X X X
6	SERVO: 740 1434 1314 883 2404 763 X X X X X X X X X X X X
7	SERVO: 740 1183 1961 1147 2428 1698 X X X X X X X X X X X X
8	SERVO: 1386 1183 1961 1147 2428 1698 X X X X X X X X X X X X
9	DELAY 2000
10	GOTO 1
11	

Fig 8

The fig 8 shows the software which converted the lead through program to encoded program generation.

VII. CONCLUSIONS

In the present work an attempt has been made to comprehend an articulated arm for visual and handling tasks. It requires a thorough understanding of fundamentals of mathematical modeling such as kinematics and dynamics, control, vision, electronics etc. In this regard, the mathematical models for kinematics and dynamics of the 5 DOF articulated serial manipulator along with various control strategies for trajectory tracking, and introducing machine vision have been carried out and presented. The forward kinematics, workspace analysis of the proposed arm was presented. Also, a CAD model was prepared using commercial software PRO-E^{TM} and is imported to ARDUINO and SERVO CONTROLLER SOFTWARE^{TM} for motion and static force analysis.

The following are the brief conclusions out of the present work:

- The Kinematic analysis of the 5-axis serial arm manipulator with DH parameter have been formulated and computed in MATLAB.
- Workspace analysis and Jacobian analysis of Manipulator was also be carried out.
- A scaled prototype of the proposed manipulator has been fabricated based on the final design. Actuation has been provided to each and every joint using servos programmed in Arduino and pick and place operation has been tested

FUTURE SCOPE

As a future scope of the work, several additional studies may be conducted.

Few of this are listed below:`

- Increasing the degree of freedom of the arm for more number of applications in task as in real time.
- Reconfigurable mechanism of the present manipulator with precise and sensor enabled gripper and joints can make the system more robust.
- An improved feed backers for the robot in the joints and links to system for which the feeding the information for the prevention or information to guide for the better solve.

REFERENCES

1. John J. Craig, Introduction to Robotics-Mechanics and Control, Pearson Pub.
2. Bruno Siciliano, Lorenzo Sciavicoo, Luigi Villoni, Giuseppo Oriole, Robotics Modelling, Planning and Control, Advanced Textbook in Control and Signal Processing, Springer
3. Saeed Nikku, Introduction to Robotics, John Wiley & Sons.
4. R K Mittal, I J Nargrath Robotics and Control.
5. M. Vidyasagar, Mark W. Spong, Robot Dynamics and Control, John Wiley & Son.
6. A. Mutka, I. Draganjac, Z. Kovacic, Z. Postruzin, and R. Munk, “Control system for reactor vessel inspection manipulator,” in *2009 IEEE Control Applications, (CCA)Intelligent Control, (ISIC)*, 2009, pp. 1312–1318.
7. M. Houry, L. Gargiulo, C. Balorin, V. Bruno, D. Keller, H. Roche, N. Kammerer, Y.Measson, F. Carrel, and V. Schoepff, “Diagnostics carried by a light multipurpose deployer for vacuum vessel interventions,” *Fusion Eng. Des.*, vol. 86, no. 9–11, pp. 1868–1871, Oct. 2011. 5, no. 10–12, pp. 1947–1951, Dec. 2010.

AUTHORS PROFILE

G Krishna Teja, Assistant Professor, Mechanical Engineering Department, Anurag University, Hyderabad, India. gkrishnatejamech@cvsr.ac.in. Has done M.E Robotics from University college of Engineering, Osmania University is an academician from 8+ years by sharing the knowledge with several graduates and postgraduates to become qualified engineers in the field of Robotics. Major area of research interests in mathematical modeling and optimal design of robotics systems and sub systems for obtaining consistency and accuracy for accomplishing the robotic tasks.

K S Sandesh, B.Tech Mechanical Engineering Department, Anurag Group of Institutions, Hyderabad, India. Runner up in the Inter-college in paper presentation in institution He is a member in Society of Automobile Engineering and also **7** taken part in fabrication of Go-kart vehicle steering mechanism.

K Sai Chand B.Tech Mechanical Engineering Department, Anurag Group of Institutions, Hyderabad, India. He is runner up in Inter-college Paper Presentation conducted at Osmania University Hyderabad on 4 Stoke Engine. Participated in Technology and career conference in JNTUH. Attended workshops on Robotics at BITS Hyderabad.

V Kalyan Sagar, B. Tech Mechical Engineering Department, Anurag Group of Institutions, Hyderabad, India. He is a member in American Society of Mechanical Engineers and also taken part in Human Powered Vehicle Competition held At VIT, Vellore, INDIA.