TWO AXIS GIMBAL SYSTEM FOR A CERVICAL JOINT MOTION

S.Aishwarya[1], P.Buvana[2], R.Deepika[3], T.Alamelu[4], Assistant Professor K.Banumathi[5]
Sandeep Narayanan. P[6], H. Krishnachandra Singh[7]

[1,2,3,4,5,6,7]*Department of Electronics and Communication Engineering, Panimalar Institute of Technology , Anna University, Chennai, India.*
Prag Robotics Pvt. ltd. Chennai, India.

---***---

Abstract — *Generally, The word 'GIMBAL' means pivoted support that allows rotation of any object in a single axis. Meanwhile, a 'TWO AXIS GIMBAL SYSTEM' means which can rotate over azimuth and elevation axes is considered. Normally, humanoid neck is complex component which provides dexterous movement in very compact form. Hence, it is difficult to imitate human neck in all aspects. The movement of the cervical spine used to support the head and generates desired head movements. Moving the head up and down is known as 'TILT' whereas moving the head in right or left side is known as 'PAN'. The range of motion like upward and downward movement is analyzed and it is implemented.*

KEYWORDS – Gimbal, Cervical joint, Pan, Tilt, System Design and Analysis.

1. INTRODUCTION

A Gimbal is a stable mechanism which rotates an object in a single, double or more axis respectively. Gimbal system is used in the cervical joint which makes the neck motion in the robot. The neck motion consist of pan and tilt. Gimbal can oscillate in three dimensions which makes the system mechanism equilibrium and directional. In this we are going to compare the gimbal system with a cervical joint of a human neck. Cervical joint means it gives posterior support for the spine and it is also connected to the skull of the human body. This gives different head movement in different postures like left turn , right turn , up lift , down lift and rotation up to 90 degree (pan , tilt). It consists of various types axis in which is gimbal system is used. A gimbal is been centered in which the rotation of the object takes place in a single, double, three to six axis respectively. The gimbal is placed along the orthogonal, perpendicular axis and other axis lies with respect to the innermost gimbal respectively. Gimbal can oscillate in three dimensions which makes the system mechanism equilibrium and directional.
For example: Consider the working of three axis gimbal camera. The three axis gimbal consists of 3 axis pan, tilt, roll. In this working the camera acts as a stationary object which focuses on a particular focusing point and the three axis gimbal can be rotated in different motion such as left, right, up, down, front, back respectively. It can be used differently as per the user convince. Each kind of motion indicates the rotation about the particular axis. The angle ranges of these motions ranges in degrees. The motion of the Gimbal is based on the IMU Sensor.

Human Neck consist of neck muscles and they are important for the motion of the head in all the directions. Neck consists of different muscles they are sternocleidomastoid muscles and the trapezius are responsible for gross motor movement. Gimbal used in various aspects for stabilization in camera and videos for the purpose of film making there are vibrations and angular motions takes place to overcome it we are using the gimbal system because it as various axis they are: Single axis, Dual axis, Three axis, Four axis ,Five axis and Six axis. In DSLR camera's the gimbal system in various axis.

For example: Zhiyum crane V2, Letus helix Jr, Moza lite 2 premium handheld gimbal, Ikan MS1 beholder gimbal, DJI ronin - M 3 axis gimbal stabilizer, Camera Tv, Optimus 3 axis camera gimbal.

2. LITERATURE SURVEY

With reference to the first literature survey papers this paper is based on PMA (pneumatic muscle actuator) in which the system is classified into two serial and parallel system where two motors and servos are used .The bionic robot adopt serial structure as they used spring instead of Cervical joint which is flexible as human neck and ring is also attached for the purpose of any kind of rotation. The kinematic analysis method has been followed (large scale rotational and small scale translation) whereas the parallel Stewart mechanism is adopted to retain the six DOF of neck movement. In inverse kinematic method (closed loop control system) analytic and numerical method are also used in that numerical method is more practical than analytic method. It uses mechatronic design method to reduce the upper platform and increases angle of movement. The MATLAB/simulation link/RTW architecture is used for the output. The advantage of this parallel structure is light weight and it can able to generate 6 DOF motion .The disadvantage in this system is spherical hinge, limited movement angle[1].

In second literature paper, they proposed to achieve the head stabilization as they tried in many ways such as vestibular organ in human leads to the locomotion of the neck to tilt and pan when it is compared to robots. Some of the robots as the sensor (artificial vestibular) system which turns the neck portion of the robots. The combination of gravity and fictitious force that are hard in angle so to reduce the drawback the inertial sensor and angular stabilization used to implement the pitch, roll operation in the human like robots .These things makes the ground based measurements accurate for the postural control and other functions. It uses direct sensor feedback (or) estimated state feedback (2 DOF) which improves the quality of vertical estimation. It may be linear or non linear based on the input. The advantage of this is it achieve the head stabilization and the disadvantage is it uses vertical fundamental for free moving robotics because of inertial measurement response[2].

In third literature paper, they proposed DOBC to reduce the disturbance observer and also in perturbation, parameter error. The higher stabilization is achieved by implementing DOBC methodology to avoid friction, turbulence problem. Azimuth method is implemented to overcome the short coming and to increase the stability the DOBC is implemented. H infinity based design is adopted in DOBC. By implementing the azimuth method we can control the object. PID, PID-I, Zero type controller and zero type plus DOBC were designed and implemented. Zero type controller is more advantageous in two axes gimbal system. Zero type controller improves the system DOBC feed forward loop (non linear friction)[3]. By taking reference over these three surveys in our paper we are implementing the two axis gimbal system. By implementing the two axis gimbal the neck is stabilized and the pan and tilt motion is achieved on the head. The movement of the head is achieved by using two axis.

It increases more stabilization, precision and accuracy of the angular movement.

3. EXISTING SYSTEM

The two axis gimbal system use spherical, hinge structure which makes the movement of the neck in very limited angles. The different methodologies are used like Quarternoid method[8] for the rotation purpose to implement the two axis gimbal which makes the system hyper complex and less efficient.

In some cases PID controller[3] is used in control system under several variable conditions which makes the overall output unstable and it is implemented in MATLAB simulation which cannot be used in real time application.

Other existing system uses the range of motion for the neck movement which is limited in the degrees for example -25 to 39 [10] degree respectively.

Other papers uses azimuth and the elevation method which is more tedious. It also uses Lagrange equation[9], mathematical model for two axis gimbal system. The overall output of these methodologies can be viewed only by simulation and cannot be used in practical way.

In two axis system (human neck) the imitation of the human neck is quite possible in robots and it increases the complexity and it cannot be light in weight. This system use mechanical method (Kinematics and inverse kinematics)[1] which are quite possible in the experimental cases but when it comes to real time applications it is much more complicated.

4. PROPOSED SYSTEM

To overcome those drawbacks in the existing system we are using simple mechanism and simple components and we have designed the two axis gimbal system. We have implemented the two axis gimbal system by using Arduino Uno (i.e, both hardware and software), IMU Sensor, Servo motor which is used for Pan and Tilt Motion. We have reduced the time complexity and it also increases the efficiency of the system. The system will also reduce the error and makes the system to work in linear motion. The Gimbal system increases the stability and also it will improve the accuracy of the system. By using Arduino software (IDE) the calibration of the sensor with the Arduino takes place and make the angles more accurate which is based on the position changed by the IMU sensor. The angles can be viewed in the serial monitor and for corresponding angles the graph can be plotted in the serial plotter in the Arduino IDE Software.

It can be implemented in mechanical method as well as in electronics method. We used electronics method by adding sensor and servo motor with the Arduino to it. In electronics method the complication of the design structure and the risk factors will be reduced comparing to the other methods. The operation of this system is very simple and less in cost. In this system pan and tilt operation is achieved. It is implemented in many places and also used in real time applications.

5. HARDWARE DESIGN

The below pictures is our proposed design for the Two Axis Gimbal System.

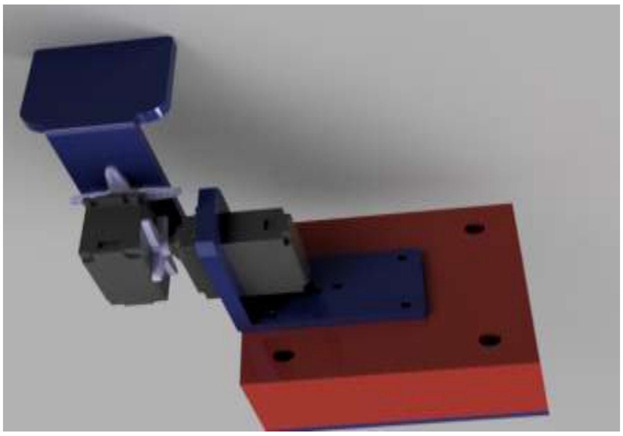

FIG 1. Top View of Two Axis Gimbal.

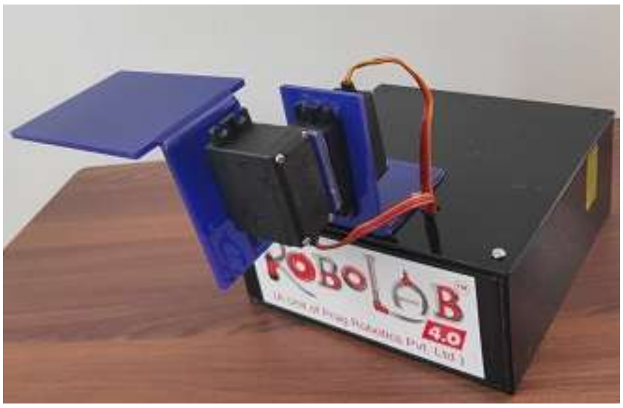

FIG 2. Side View of the Two Axis Gimbal.

6. FLOWCHART AND ALGORITHM

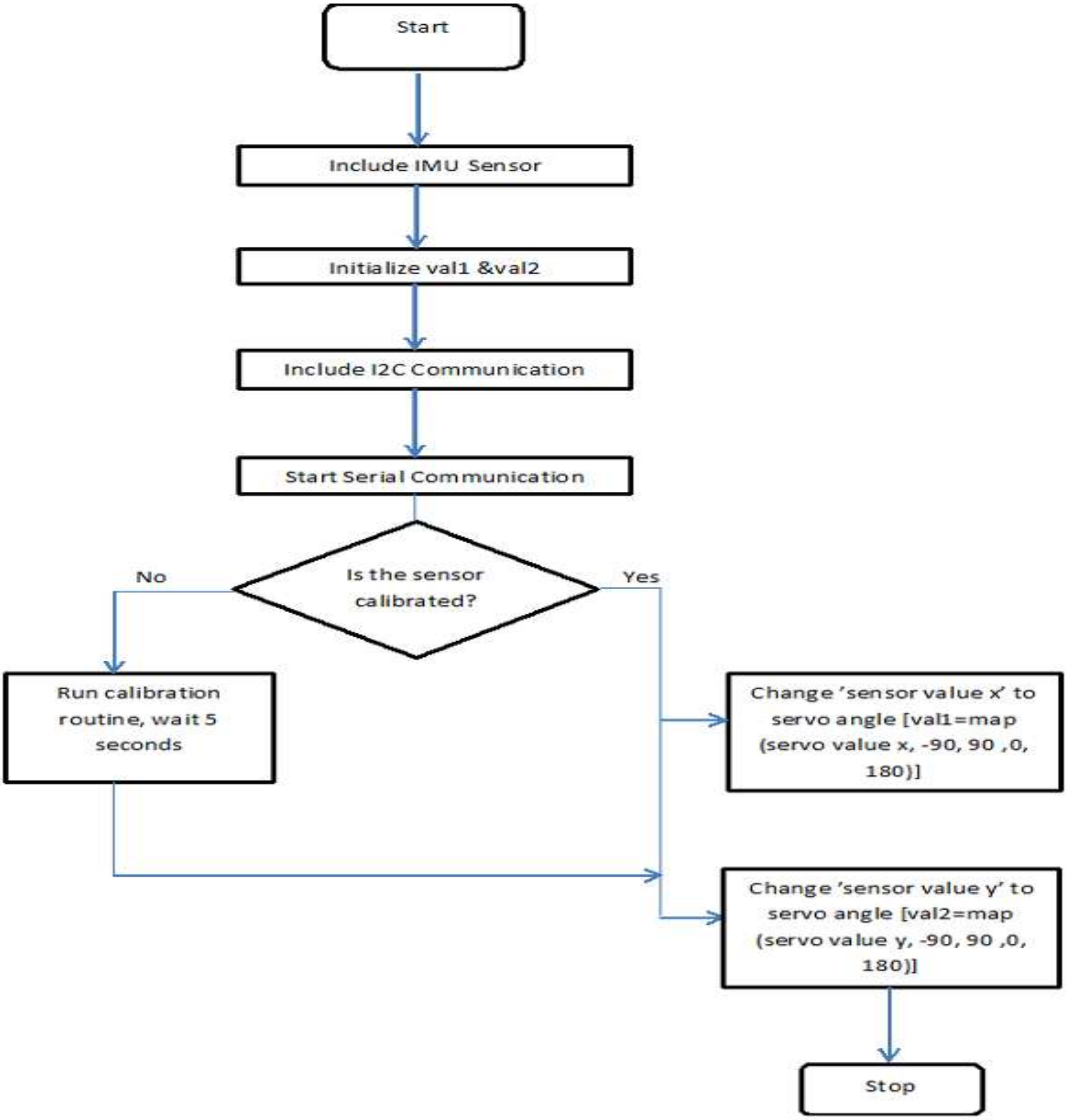

FIG 3: Optimized Flow Chart Working of Gimbal.

In Fig 3, the flowchart initialization part is done by integrating the Arduino with the IMU sensor[2]. After that the communication between the I2C devices starts .Later the Arduino communicates with the servo and the sensor communicates with the I2C devices. After the sensor is been calibrated the movement of the servo motor takes place. The sensor value changes according to the movement of the servos. These values are mapped to the servos and movement takes place. After the process is done the calibration part takes place in the serial monitor. In the serial monitor the calibrated values and the angles of the servo motor is been displayed.

We can also view the calibrated values and the angles of the servo motor in the serial plotter as a graph in the Arduino IDE Software. By Fig 3 in this algorithm we can achieve 0 to 180 degree Pan and Tilt operation.

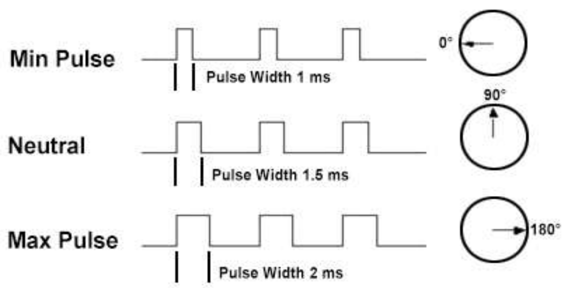

FIG 4. Movement Based on the Servo Angles.

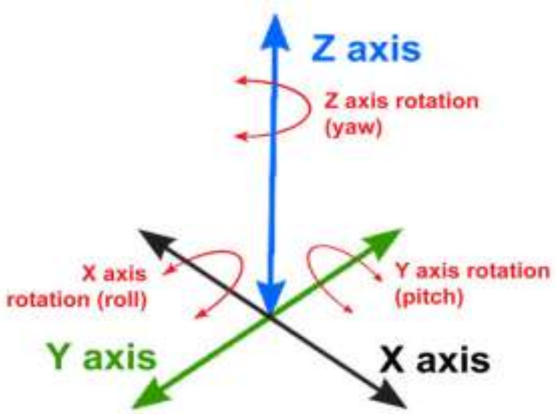

FIG 5. Representation of the Axes.

In Fig 4, It explains the representation of the 2 degree of freedom (2 DOF). It consists of X and Y Axis which makes the Pan and tilt operation (Pitch and Yaw). In this we are not using Z Axis. In our proposed design the 3 degree of freedom (3 DOF) is reduced to 2 degree of freedom (2 DOF). By using 2 DOF the Pan and Tilt operation and it is been achieved.

7. WORKING MECHANISM

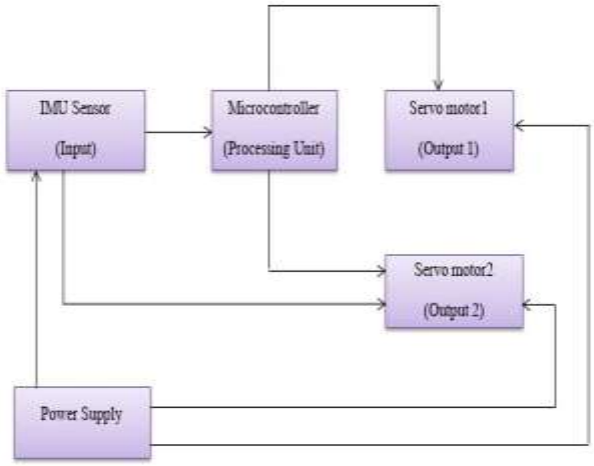

FIG 6. Block Diagram.

Initially the power supply is given to the IMU Sensor and both the servo motors of 1 and 2. The IMU Sensor is connected to the Microcontroller and the servo motor 2. Then the microcontroller which is a processing unit is connected to the servo motor 1 and 2.

(7.1) IMU Sensor: The IMU Sensor plays a major role in this operation. In the IMU Sensor the Vcc Pin is connected to the Arduino 5V (Volt). The digital pin in the Arduino A4 Pin is connected to the Serial Data (SDA) and A5 Pin from the Arduino is connected to the Serial Clock (SCL) in the IMU Sensor.

(7.2) Microcontroller: The microcontroller is the Arduino which is the main processing unit. It integrates the IMU Sensor and the servo motors of 1and 2.

(7.3) Servo Motors: The input to the servo motor connected to the digital pins of the Arduino. When the IMU Sensor changes the position simultaneously the servo motor changes the angles. The IMU Sensor operation will take place in the corresponding servo motors of 1 and 2 (PAN AND TILT). Based on the connections the servo motor 2 does the Pan operation which makes the servo motor 1 to make right and left. The servo motor 1 does the Tilt operation by keeping the servo motor 2 stable.

8. OUTPUT

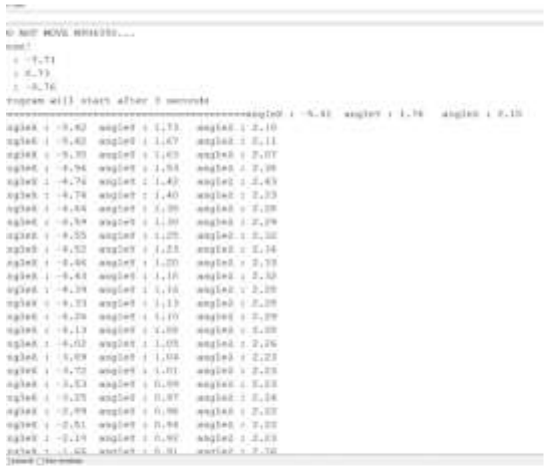

FIG 7. Serial Monitor of Arduino IDE.

In Serial Monitor, when you give the power supply to the Arduino you have to wait for 6 sec. After that we should turn on the Arduino. In the serial monitor we can see the command DON'T MOVE MPU6050 command line followed by done. (This line shows that X, Y and Z calibration is done). If we keep our sensor to -7 it will detect -7. When all the process is done the program will starts after 3 sec. In the program the X, Y and Z axis shows what is happening with the sensor (only X and Y no Z axis). The Servo motor takes the value up to 180 degree. The angle value in the Serial Monitor does not go beyond 180 degree based on the need the value can be changed within or up to 180 degree.

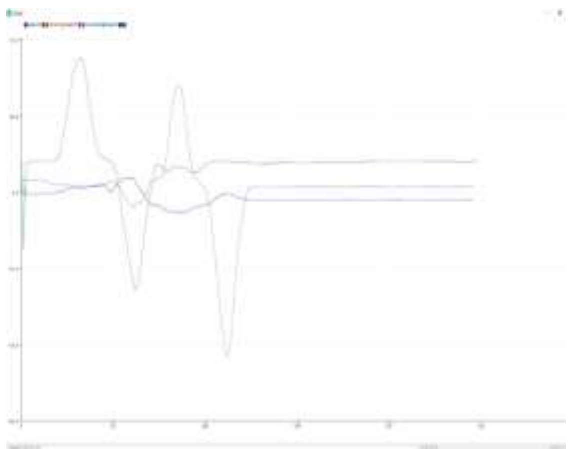

FIG 8. Serial Plotter of Arduino IDE.

In the Serial plotter we have three color. The Green color line takes the X angle. The Brown color line takes the angle Y. The blue color line takes the angle Z. When you move the sensor to left and right, the value will change with respect to Time. When we move the sensor to the angle X (Green line) to Positive (or) Negative It will go Up and Down, and when you see the values of the graph it will be like 0, +10 which is above and below -10. So if you move the sensor to the angle 10, 20, 30 like that, the green line will move up.

Then, when you see the Z angles, we haven't move the sensor in the Z direction so there will be very less movement. we only have used X and Y axis in the Serial Plotter so you can see the green line going Up and Down and for the brown it is also going up and down. At first the sensor is moved to X axis so the line is moving from Up and Down and when moving to the Left side the line again it moves from Up and Down, similarly for Y also this moves are applicable.

Thus the Serial Plotter is been plotted with respect to time and with the angles. The angles is been obtained by integrating the IMU Sensor with the Servo Motor. Based on the movement of the IMU Sensor [2] the angles in the servo motor changes accordingly. Thus the serial plotter is been obtained by the movement of the sensor with respect to the angles of the servo respect to the time.

9. CONCLUSIONS

In this paper we conclude that two axis gimbal system used in Cervical joint is constructed simply by using simple components like Ardiuno UNO, Sensor and Servo motors. This makes more cost efficient and the output values and angles will be more accurate.

In future the Two Axis Gimbal can also be rooted in the Neck of a Humanoid robot which will resemble like a human being. These robots can also be used in restaurants (or) in any other social areas to interact with the Kids as like a human beings. It can also be used in defense purpose to act similarly like a human being in a war field whereas the enemies will wont analysis the Robot like soldier in which human life can be saved. The output might be differing based on the design implementation.

10. REFERENCES

[1] Yingmin Zhou, Hongtai Cheng, Hongfei Jiang and Lina Hao. "Design of a PMA-Driven Bionic Neck Robot with a spring spine," 2017 IEEE, Oct 17-19,2017, Beijing, China.

[2] Idlar Farkhatdinov, Hannah Michalska Alain Berthoz, Vincent Hayward, "Idiothetic Verticality Estimation through Head Stabilization Strategy," IEEE 2019,10.1109/LRA.2019.2913790.hal-02113171.

[3] Wei Ren, QI QIAO, Kang Nie, and Yao Mao. "Robust DOBC for Stabilization loop of a Two-Axes Gimbal system," 2019 IEEE, August 22, Beijing 100039, China.

[4] Franco P.L. Franco and Denis S. Loubach and Andre R. Fioravanti ,"An Embedded System Design for a Two Axis Camera Platform Control used in Unmanned Aerial Vehicles", IEEE 2017,Regular Research Awards Grant, Sao Paulo Research foundation(FAPESP).

[5] Takafumi Nishioka, Department of Education, Hiroshima University, Hiroshima, Japan, "Gimbals Control with the Camera for Aerial Photography in RC Helicopter," International Conference on Control, Automation and Systems in COEX, Seoul, Korea, 2008 Oct. 14-17, 2008.

[6] D. Steyn, "Variable speed Scissored Pair dual gimbal control moment gyro for Nano- Satellites," Ph.D. dissertation, Dept. Electrical Electron. Eng., Stellenbosch Univ., Stellenbosch, South Africa, 2015

[7] B.Gao, Z. Zhu, J. Zhao, and L. Jiang,"Inverse Kinematics and workspace analysis of a 3DOF flexible parallel humanoid neck robot," "Journal of intelligent and robotic systems", pp.1-19,2017.

[8] Meenu Selvarajan, C M Ananda , "Quaternion Based Pointing Algorithm for Two-Axis Gimbal of Micro Aerial Vehicles," IEEE International Conference On Recent Trends In Electronics Information Communication Technology, May 20-21, 2016, India.

[9] Maher Abdo, Ahmad Reza Vali , Ali Reza Toloei, Mohammad Reza Arvan. "Modeling control and simulation of two axes gimbal seeker using fuzzy PID controller," The 22nd Iranian Conference on Electrical Engineering (ICEE 2014), May 20-22, 2014, Shahid Beheshti University.

[10] Edgar Flores and Sidney Fels, "A Novel Robotic Neck for Realizing an Anatomically Accurate Android Head Targeting Facial Perception Research," The 23rd IEEE International Symposium on Robot and Human Interactive Communication, August 25-29, 2014. Edinburgh, Scotland, UK.