A Review on Design and Analysis of a Hexapod

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Abstract

The principle motivation behind the work is to present a fully fabricated Hexapod. Hexapod is a robot that has six legs for movement and thus quite a number of degree of freedom. . Numerous studies have been completed in examination focuses. Moving robots have pulled in significant consideration for a very long while now, on the other hand, just as early as this past year scientists have produced navigator robots, planned and assembled to fulfill the imagination, with exhibitions that can be suitable for handy applications. This paper gives an outline of the best in class on hexapods by alluding both to the early plan arrangements. Cautious consideration is given to the fundamental design issues and requirements that impact the specialized possibility and operation execution. A design flowchart was plotted with a specific end goal to efficiently plan a hexapod. Since the robot has numerous legs, the robot is effortlessly customized to move around in light of the fact that it can be designed to numerous sorts of gaits, for example, tripod, and wave, ripple and quadruped gaits etc. House of quality was used to compare and finalize among the probable design. A novel design has been created with CATIA. Mainly, the undertaken design outline takes into account the fundamental features, such as basic structure and mechanical configuration, electronics schematics, motion planning, payload, and walking gait. Kinematic as well as Dynamic Analysis had to be done using DH forward and Inverse matrix method. Simulation has been done in V-rep and excel simulator. Stress and displacement analysis was done for the feasibility of the model to sustain the weight of the body. Estimated physical parameters have been calculated. Control system design, gait implementation body manufacturing has been discussed. Bill of materials was generated and fabrication of Hexapod was completed. Future possibilities have been discussed.

Introduction

Dominance of six legged species in insect world is quite clear and obvious. They use the six legs for bigger stability base and also the higher number of degree of freedoms being available helps in moving in uneven terrain faster and smoother. Hence the concept of Biomimetic hexapod to dominate the robot world in context of stability. With the vast use of hexapods in

Future we can excavate mines, explore extra-terrestrial bodies, simplify search and rescue mission and thus overall making human life hazard free and safe. Use of Hexapod by ESA in Rosetta mission showed the world an idea for movement of robots on the surfaces of extra-terrestrial bodies. Mangalyaan mission using serial Hexapod is worth mentioning. With India's ambitious Mar's mission II, the extensive research in the field of hexapod is speeding up. This gives me the motivation to undertake this project.

Literature Review of Hexapod Structure

The mechanical and operational mechanism of a hexapod robot is in view of creatures (basically insects), from the biomimetic standards [4], science is light of the impersonation of existent components in nature, attempting to take in its working sand applying such information in the undertaking of simulated instruments like the natural ones. "Bio mimetic" is the merging of the Greek expressions "bios", which implies life, and "mimesis", that implies impersonation. Accordingly, it might be said that the biomimetic is the impersonation of living things. These days, the biomimetic speaks to an examination zone that is in awesome advancement in the field of the science and innovation.

Innovation rises speedier by adjusting another's thought to add to one's design, model and new framework control. LAURON is a standard sample; a six-legged robot which has been created at the Forschungszentrum Informatik Karlsruhe (FZI) in Germany. The primary LAURON project was constantly enhanced until the most recent task called as LAURON IV [1]. The hexapod robots have different sorts and capacities. Many are truly straightforward in the outline and control structure, where as some are of complex structure and control. Case in point, in the operation framework, the robot [2] is fit to perform different tasks utilizing a remote control at unsafe range which is can't be secured in person. Viz. observing radiation risk.

Literature Review of Control System

The designs of hexapods from every papers have ample amounts of particular contrasts. RHex grew by [3] utilized Maxon sort motor with a 33:1 gear reduction fueled by a 22V cell. The robot leg has 2 DOF. As indicated by the author, the strategy is anything but difficult to construct and keep up the robot and no friction amid springy movement. This is most appropriate for stair climbing. Another, Bill-Ant-P robot done by [4] was fabricated with carbon fibers and 6061 aluminum. It utilizes MPI MX-455HP hobby motors for its maneuverability, more torque value, and more DOF movement. They have 8.35kg-cm of torque, can turn around a 60 degree in 0.18sec, and has a smaller dc motors that devours 1155mW of torque at standing torque.

The paper presented by E. Burkus et.al. [5] discusses about 'Gregor'. This robot improvement model had Autodesk Inverter 9.0 to characterize attributes of the components, for example, weight.

To arrange of the limitations that can be effortlessly traded into the dynamic simulation process, Rhinocerus 2.0 software was used. MSR-H01 hexapod grew by Micromagic System was designed and assembled from 26 accuracy laser-cut 5053 aluminum components [6]. Hexapod designed by D. Belter et.al.[7 controlled 18 servos by interfacing it with the Arduino Decimilla board ,which was favored above other micro controllers. Theye did this by using Devantech SD-21 board. The product utilize Matlab to control the servo controller.

To control the robot leg, Jacobean Inverse matrix method was utilized to characterize the position of joint, angle and legs. The notes by Polulu Co-operation showed that hexapod can use Dynamixel RX-28 by ROBOTIS [8] as joint servos, which is a complex actuator module. The control board taking into account the 16-bit AVR ATmega256 and cable communicates with external personal computers. The controller to robot communication was done by sending data parcels to joint servos and various sensors and vice-versa. The main controller communicated with the robot by sending and accepting data parcels to the servos and sensors. Ragno [9] was built of the dimension, 33 cm long and 30 cm wide. It weighted 2.15 kgs. Wireless communication as in Bluetooth was used for serial communication between the on-board and off-board parts.

Literature Review of Robot Movement

The robot's forward movement using hexapod legs is called gait [7]. There are mixtures of walking pattern available and the well-known gait utilized by hexapod is called Tripod stride. In this tripod walk, three feet of hexapod is dependably in contact with the ground for the entire time [10]. The journal by [2] shows how the author utilized tripod stride in light of the fact that it is stable. The initial phase in walk, angles the beginning stance of all legs is chosen, and end point position is characterized as the "reference position". In the work published by [8], the hexapod robot likewise utilizes tripod walks, the body component and bolstered by three legs. The work is centered on the energy development of bot, Kinetic mechanism and the path taken [12]. It is about the practicality on how the robot navigates. The imperative viewpoints thought seriously about are the inertial edge, train referenced direction arrangement of suspension.

In catastrophe recovery [11], mentioned bot utilized a couple of variety of gait ment to move it in at all sort of landscape. On even landscape, the gait utilized is alternating while on uneven territory, Wave gait is preferred. The most back leg is begin made headway while we compare it to all the other legs. The stride is exceedingly steady since one leg is lifted above the ground at once. Main purpose behind picking this gait is the best strength edge for uneven territory

route. Wave walk motion embracing the control calculation with an angular position data and torque command yield [9].

Objectives of the project

Primary objective of the project is to materialize the design and fabrication of Hexapod in the given time frame. In which the sub-divisions are,

1 Research on Bio mimetic Hexapod

2 Identification of key features and main design characteristics of Hexapod.

3 Building a solid 3D model of the robot using CAD software.

4 Validation of the CAD model by Kinematic and Dynamic simulation.

5 Use of V-rep, Excel sheet for simulation.

6 Material procurement for the simulated model.

7 Writing algorithms for control of hexapod using adequate Gaits.

8 Write the PIC program for this robot.

9 Optimization of the control system.

10 Assembling the Hexapod in line with the 3D model.

11 Demonstration of final Hexapod.

12 Realization of further improvements.

Classification of Hexapod:

Hexapods are broadly classified into two different categories.

Circular (Radially symmetric)

Rectangular (axis symmetric)

Modelling of Bio-mimetic leg:

The nature inspired leg of a hexapod is basically consists of four major parts.

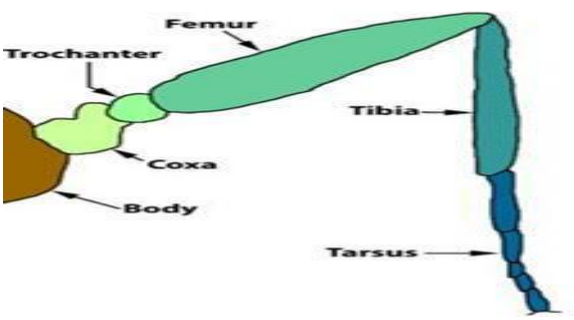

Figure: Bio mimetic leg

These parts more or less remain same across the insects' family. Tarsus is neglected for design.

Degree of Freedom Calculation:

Each leg has three degree of freedom neglecting Tarsus. This can be shown as a RRR manipulator. The body of the hexapod can also move in six different directions in the three axis providing it a total of six degree of freedom. Hence total number of unrestricted degree of freedom enjoyed by a hexapod is 6*3+6= 24 DOF.

Structural Model of Hexapod

This segment of the work talks the subtle elements on how the physical model is being created. The improvement begins by outline and portrayal a few design of hexapod robot with distinctive angle and criteria until to the basic schematic design before the hexapod robot stands on its feet for being tested. The plans of hexapod had been designed in eight distinct outlines and with each having their diverse shapes, criteria, details, preferences and weaknesses. The eight plans of the hexapod robots are indicated in Table 2. From the outlines specified in Table 2.a, the main specification of every robot are portrayed in the Table 3. The detail of the robots covers a couple of fundamental angles.

Our leg design should be based on three major factors.

1. As light weight as possible
2. Minimum Bending in all direction
3. Can support the weight of the robot.

Drafting using CATIA

After deciding the best case design we moved to the software drawing of hexapod. We had to know the dimension of each part of robot for that. CATIA software by Dassault systems was used for the design. CATIA stands for "Computer Aided Three Dimensional Interactive Application". CATIA is user friendly. It gives real images, detail portraits, and steps for demonstrating design. It also supports surface modelling. It provides with unique drafting operation which can be handy with details while true prototyping. It also provides simulation, animation, weight estimation by applying materials to robot body; which includes both metal and non-metal. Using this material selection acrylic sheet and aluminium was chosen to build the robot boy for their light weight. Using CATIA one can also export or import part files, drawings to or from other software.

Steps followed in CATIA design are:

1) Part modelling of the different parts of the robot in CATIA V5 starting with leg. (using the element of symmetry helps in design)

2) Assembling of the parts in CATIA V5.

3) Defining of joints and contacts for the robot in CATIA Sim Designer.

4) Drafting of the novel design.

5) Exporting of the design for further simulation using V-rep and ADAMS.

For CATIA design the aforementioned dimensions in table were used. The platform diameter is taken as 110 mm. Although there is still scope for future improvements and corresponding changes in the design of Hexapod.

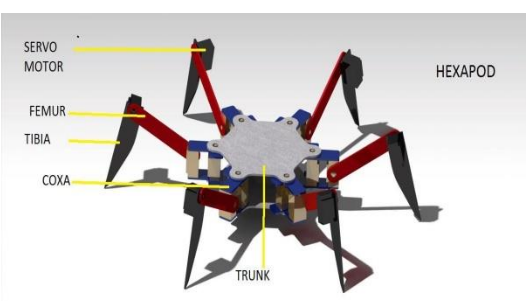

Figure: 3D model designed in CATIA

Kinematic Analysis

For a stable and balanced structure, the COM (center of mass) of the robot must lie inside the circumference made by the pivot points. Best case scenario is the COM should lie below the circle made by the point of pivots of tibia for stable equilibrium, but not necessarily. If the COM is outside the circle, the robot will fall off.

Forward Kinematics is the part of kinematics where the end position is being calculated. In case of a serial link i.e. the leg of the robot, it is the position of end effector in frame of reference of the COM. If we know the servo position, link lengths, and angles, we can know the end points of the leg. Thus this kinematics is deterministic, as there can be only one solution to the equation. But it is hardly useful here. As giving a servo a motion leads us to only one point. But if end point changes, the entire leg have to change the orientation.

This leads us to Inverse Kinematics. Inverse Kinematics can be solved in two different ways.

Analytical-

Geometry is of course one way of solving the Inverse Kinematics. It helps when the number of links are less. You can simply draw the arms using the angles shown, and the equation can be solved. It is basically a hit and trial method.

A more efficient way is matrix multiplication. Rotation and translation matrix is being used for the reverse translation of the end point to the base point. In hexapod each leg can be a RRR manipulator hence rotation matrix is multiplied thrice for calculation.

V-Rep Analysis

Analysis of the design and simulation are the ways to eradicate or short out manufacturing delays due to design imperfection, and hence the cost of prototyping. V rep analysis thus helps in the better understanding of simulation. It helped in creating embedded scenario and applications for robot. Basically 3D simulation helps in understanding and validating the design. V-rep is one of those robotic simulator. It is developed by 'Coppelia Robotics' and is written in the programming language 'LUA'. For better understanding of dynamics a simulation of Hexapod using V-rep was done and results were discussed.

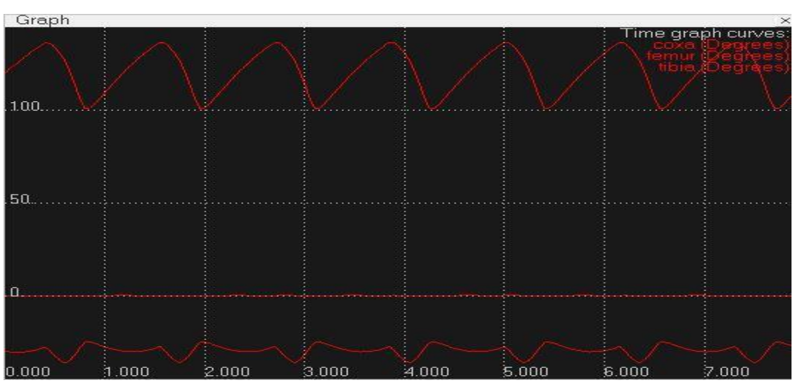

Figure: Joint Displacement

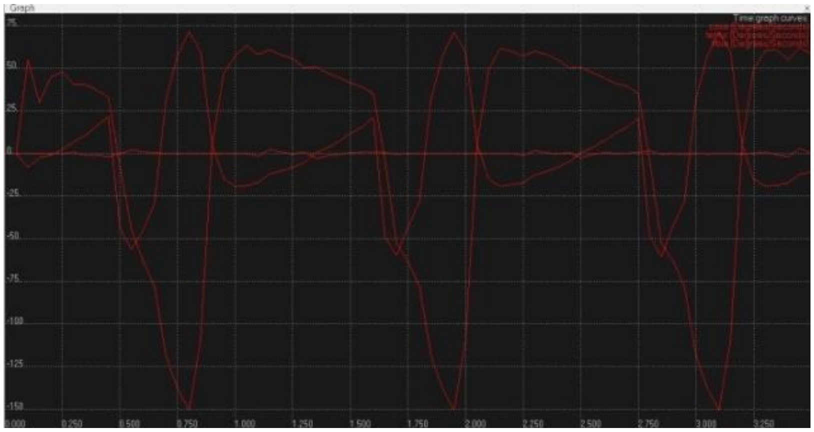

Figure: Joint Velocity

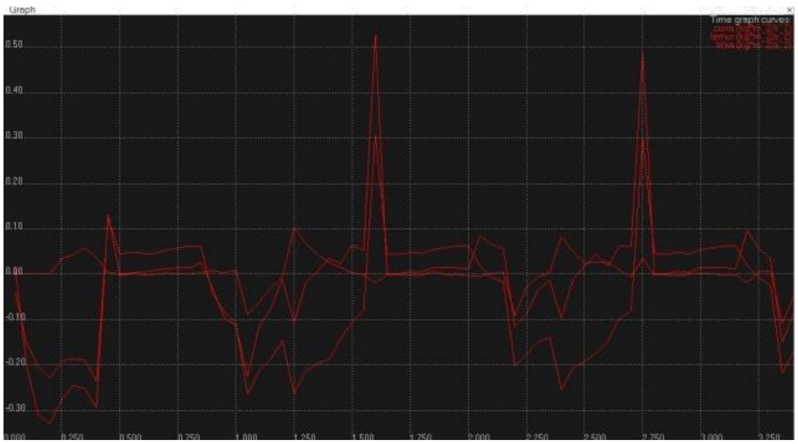

Figure: Joint Torque

Discussion of Error

Due to the capacity limitations of hexapod, some design changes took place after consideration of body weight. Now evaluating the simulation time of Hexapod for covering distance with the realistic time we get some error. Most of the error in practical experiment was due to connection misfits, structural deficiencies and friction.

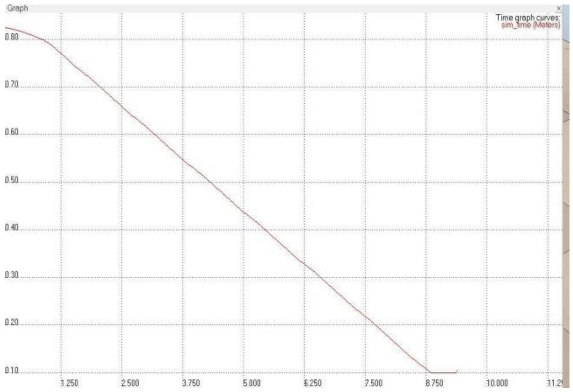

Figure: Simulation time graph

Standard percentage of error calculation was done using the formula

$$e = \left(\frac{Te - Ts}{Ts}\right) \times 100$$

S.no	Distance In meters	Simulation time Ts	Practical time Te	Percentage error E
1	0.2	2.9	3.2	10.34
2	0.4	5.1	5.5	7.85
3	0.6	7.5	8.1	8.04
4	0.8	10.1	11.06	9.56
5	1.0	12.4	13.62	9.82

Table 5: Error calculation

The percentage error shows that there are some initial glitches while booting up the robot but as the robot moves on the error for the successive distance period keeps decreasing when robot is in full forth, and then again after some time the robot starts to slow down. The error here can be attributed to structural faults, electronics signal interference etc.

Conclusion

This research is motivated by the need for mobile machining systems to remove humans from hazardous and inaccessible environments. The research analyzed the kinematics, dynamics, and stability requirements for mobile machining system based on hexapod walking robots. The major contributions of this dissertation are, model selection based on the House of quality was done. The structural parameters of a HWR were selected, the physical size of the robot was determined. A 3D virtual prototype robot system has been created CATIA V5.The design then exported to V-rep workbench through CATIA to simulate it in real time. V-rep simulation validated the design. Excel spreadsheet simulator was created for better understanding of IK.An accurate and concise analytical inverse kinematic solution for HWR was developed. Solidworks analysis for stress and displacement deformation was carried out. Bill of materials was finalized. A bio-inspired reactive stability control strategy, gait algorithm was developed. Fabrication of the hexapod in line with the developed strategy was completed. Experimental demonstration of the robot and embedment of modern technologies for productive work was done.

Future Work

As the project has reached the time limit, the future possibilities to be thought of are further optimization of the design parameters to a prescribed workspace along with GA and Fuzzy Logic implementation in gaits. Developing a full scale industry oriented

hexapod in line with this parent design should also be kept in mind. Implementation of sensors for data collection can be implemented for better feedback and complex operation of the Hexapod.

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