Design and Fabrication of Octopod for Survey and Rescue Operation

V Arun Kumar1*, B MeenakshiPriya2, P T Bijoy Antony3, Adithya B1, Hari Vikinesh M3

1Assistant Professor, Department of Mechatronics Engineering, Kongu Engineering College, Perundurai, Erode, India.
2Professor, Department of Mechatronics Engineering, Kongu Engineering College, Perundurai, Erode, India.
3UG Scholar, Department of Mechatronics Engineering, Kongu Engineering College, Perundurai, Erode, India.

*E-mail: bijoy7335@gmail.com

Abstract. Although wheel is an ideal method of locomotion and the invention of the spoke wheel made a wheel lighter and swifter, a wheel cannot function well on slanted or rough surfaces. Further, the load support of the wheel is limited to a point of the whole wheel in contact with the ground. In rough and rocky terrains, wheels become ineffective or not able to serve the purpose. On realizing this fact, a new design and fabrication is suggested and a walking robot is designed accordingly. In the practical life, the usage of robots has been felt especially in search and rescue operations, extraterrestrial exploration and many more such applications. In these areas, the existing wheeled robots are not able to perform well and hence they can be replaced with walking robots of special design. In distant areas, many expeditions of walking robot need the tele-operation mode. Yet, sensing the terrains and controlling the robots become difficult for a human operator with the available capabilities and hence the walking robot should be designed in such a way that even with limited feedback from the remote operator, it should have adequate autonomy to take due advantage of its competency and capabilities. The paper envisages a new method of real-time motion planning on rough and rugged surface and in this paper, an octopod is designed, developed and fabricated accordingly.

Keywords. Octopod, legged locomotion, bio-inspired robot, mobile robot.

1. Introduction and background study

There has been a ceaseless study since 1960 on walking robots. Six years after this marathon study, the first quadruped robot was developed and the same was named as “Phoney Pony” and McGhee and Frank were the people behind this development. Subsequent to this major breakthrough, many quadruped robots were designed and developed and the robots developed by Spenneberg, Strack in 2005 are significant developments. With this development, the next level of hexapod robots were designed and studied for their performance. The scorpion robot was developed with three prominent body parts and eight homogeneous legs. DC motors were used to control the leg joints with high gear transmission ratio. But in Octopod robot, the independent drives are used to drive the C -shaped legs and these drives are placed on both sides of the robot. The robot’s movements are controlled in two ways i.e. with the adjustment of the speed of the legs and by suitably adjusting the swing motion. The movement of the robot is thus accomplished by adjusting the speed of legs and also by adjusting the
swing motion of robot’s mechanical tail. Another robot vehicle with eight wheels and legs has been designed and named Halluc II.

There was a study to develop a six-legged robot on the basis of insect behavior [1]. Detailed study was made to analyze the mechanical construction, the devices and the electronic control system installed in the robot’s body and a presentation was made accordingly. The inferences from these experimental studies revealed some similarities between the characteristics of animals and the robots and these studies and results gave an insight to develop a CPG model. Moreover, the other salient advantages and features of the tick–slip CPG model proposed were also taken into account.

Locomotive behavior of animals has inspired to develop and design robots on the similar behavioral pattern (“bio–inspired robots”) [2]. Here, in this case, the complete movements of a spider (Ornithoctonushuwena) like the leg movements, Centre of mass, joint rotation of angle and the kinematic characteristics were fully observed and placed on record. The results reveal the positioning of legs in different phases, first set comprises of four legs, two legs number one and three on one side and number two and four on the other side and two other sets consist of 8 legs are available to support and drive the motion of the spider. It is also evident that the spider is able to increase its velocity of movement by enhancing stride frequency and the study elucidates on the locomotive behavior of animals.

In another study [3] the human actions were fully observed like how a human walk by closing his eyes in rough and rugged terrains. The robot was designed by imitating the above human behavior of blind walking. In this designing, the robot can adjust the foot height if it collides with any obstacle to manage to overcome the objection. Like the human blind walking, the robot’s foot also makes attempts in different odd locations before stepping into the places. The report gave an insight to develop the robot on studying the human behavior.

One more study [4] has been made with an objective to get fully integrated robotic solutions in kinematics, topology, architecture and command. This offers a new design approach for locomotion system of robot that can be configured on its own. This design has been evolved with the dynamic simulation and optimization through artificial evolution.

In yet another study, [5] attempt has been made to develop a robot to walk on a flat and hard surface performing both kinematic and dynamitic stimulations. Different non-linear mechanical oscillators have been used to drive the robot legs. Central pattern generators are used in the robot and the gait proves to be stable in this pattern and this study inference has also been taken into account.

Most of the robots already designed and developed or under development mainly for the purpose of surveillance search, rescue and attack purpose in military applications are either autonomous or remote controlled. Wheels are primarily deployed in all these designs to facilitate movement and for space exploration on terrestrial surfaces.

The above study reports are mainly conceptual papers which are the precursors for development of a full-fledged octopod. The study on the behavioral patterns of insects, animals and human beings were the curtain raisers for development of the eight-legged robots. The present wheeled robot models have difficulty in moving the forest environment with lopsided, uneven and rough surfaces with rocks, trees, bushes blocking the path. On the other hand, these robots could be easily identified during surveillance since they are driven by wheels and all these limitations with the earlier papers have been overcome in this paper by developing the Octopod robot model which has become the suitable model in rough, craggy and rugged terrains that can be useful in larger way including military applications.

2. Proposed method

In the current work, the robots are designed with legs instead of wheels which offer the robots to overcome the challenges faced in all military applications and other related operations in similar environments. Legged robots will have more suitability in surveillance search, rescue and attack purpose in military applications with camouflaging effect since the legs will resemble like those of animals and will enhance the stability and traction unlike wheeled robots.
Main body and eight legs are the two major components of the design of robot. The legs are designed in similarity to the insect and hence all the eight legs are fabricated with identical dimensions. Servo motors with the torque of 15 kg are used in each joint and interfaced with the Arduino Mega 2560. 11v, 500mah, 20 C discharge battery is used to power the robot. Three servo motors are used to control the movement of each leg and hence totally 24 servo motors are used to control all the eight legs of the robot. All these servo motors are interfaced with Arduino controller.

In addition to these 24 servo motors, two other servo motors are used for controlling the XY axis movement of the camera. The weight of the robot is calculated 500mm x 200mm x 2.5 kg. The octopod finds its place in the Cartesian coordinate system. The robot is able to stand in four legs at every gait phase and thus gets the support polygon (quadrangle). Accordingly, the walking algorithm of the robot is designed in the manner that the Centre of gravity of the robot is not deviating during the movement.

3. Design specifications
Robot’s design has two major components, i.e. the mechanical part and electrical part. The first part has the body base, legs and connectors and the second part is equipped with the electrical circuit consisting of servo motors, microcontroller board, LiPo battery and wires. Both the mechanical and electrical parts work together with synergy and enable the octopod to affect the walking sequence. The locomotion sequence takes place once the power is drawn and as conditioned by the microcontroller. The components primarily used in the octopod is shown in table 1. The mass of each component is shown in table 2.

| S. No | Components | Description |
|-------|------------|-------------|
| 1     | DC Servo Motor MG995 | 4.8v, 5 mA, 9.0 kg-cm |
| 2     | Micro controller | ATmega2560 |
| 3     | ABS Plastic | Thermoplastic Polymer |
| 4     | Body Base | Acrylic Glass |
| 5     | Servo Connector | ABS Plastic |
| 6     | Leg Connector | ABS Plastic |
| 7     | Leg | ABS Plastic |
| 8     | Wires | Connects servos motors, Controller board |
| 9     | Bolt and nuts |
| 10    | LiPo Battery |
| 11    | LM2596 Converter |

**Table 1.** List of components used for octopod fabrication.

| S. No | Materials used | Mass |
|-------|----------------|------|
| 1     | Motor mass     | 1.32Kg (24x55g) |
| 2     | Servo Connector| 50.48g (8x6.31g) |
| 3     | Frame          | 400g |
| 4     | Leg            | 211.6g (8x26.45g) |
| 5     | Leg Connector  | 164.32g (8x20.54g) |
| 6     | LiPo Battery   | 195g |
| 7     | Total mass (W) | 2.341kg |

**Table 2.** Mass of the components.
3.1. Servo connector
Servo connector, leg connector and the leg are the three components used in designing the walking leg. Both the servo motors are connected with the body of robot by the servo motor which is a clamp like structure. It plays a key role in carrying the leg and leg connector. The servo connector weighs around 6 gm and the image are shown in figure 1.

![Figure 1. Servo connector.](image1)

3.2. Leg connector
Three components are used in designing the walking leg of robot and the second important component is the leg connector placed between the servo connector and leg. This is an intermediate clamp used to hold the servo distinctly. The image of the leg connector is shown in figure 2.

![Figure 2. Leg connector.](image2)

3.3. Leg
The last part of the walking component is the leg and it is designed in a manner to withstand the stalling created by the servo motor. The image is shown in figure 3.
3.4. **Servo motor**

A servo motor is regularly utilized if an article should be moved or to be turned. It facilitates turning of a thing with precision. We can get an extraordinarily control using servo motor. 24 servo motors are used to move 8 legs of the octopod. The following Table 3 denotes the specifications of the servo motor.

| S. No | Parameters | Dimensions     |
|-------|------------|----------------|
| 1     | Height     | 42.9 mm        |
| 2     | Width      | 19.7 mm        |
| 3     | Length     | 40.7 mm        |
| 4     | Torque (T) | 9.40 kg-cm     |
| 5     | Angular velocity | 4.8v:0.20 sec/60deg |

3.5. **Arduino UNO**

The Arduino UNO is a microcontroller board maintained with the chip ATmega328P microcontroller and made by Arduino.cc. The Arduino IDE (Integrated Development Environment) is used to program the Arduino UNO. The Arduino board is powered by a USB connect or by an external 9V battery. The algorithm is fed into the Arduino board using USB A to B cable. The specifications of Arduino are shown in table 4.

| S. No | Parameters       | Details                  |
|-------|------------------|--------------------------|
| 1     | Manufacturer     | ATMEL                    |
| 2     | Model number     | ATMEGA2560               |
| 3     | Memory           | 256k bytes (flash)       |
| 4     | I/O ports        | 86                       |
| 5     | RAM              | 8K bytes                 |
| 6     | Timers           | Three 8bit and One 16 bit|

3.6. **CAD modelling**

SolidWorks software is used in designing the robot and the drawings for various parts are made first to the specified dimensions and then assembled. Selecting solid works against AutoCAD is preferred for the ease and comfort when compared with the other.
3.7. Electrical Section
The Electrical Part has the circuits of both the regulator and microcontroller. The microcontroller circuit is built using a microcontroller development board and all other circuits are built on a dot board. Four regulators are connected in series in the regulator board. The servo motors are actuated by the PWM signals from the microcontroller. The real time electrical circuit is shown in the figure 5. The 12V DC supply from the li-po battery is converted to 5v DC supply by the regulator circuits. Then this 5V DC supply from the regulator circuit is distributed to the servo motors. The Controller board is powered by a separate 5V battery.

3.8. Mechanical Section
The mechanical part has eight legs and acrylic base. Each leg has three components, the connector, the leg connector and the leg. Every part of the leg is connected to the other part by servo motors. The first two servo motors are connected together by another servo motor and the first servo motor is connected to the leg with the frame. The second servo’s shaft is connected to the leg connector. The leg is connected to the third servo motor. The shaft of the third servo motor is connected to the other end of the leg connector. The entire electronic system is placed inside the acrylic frame. The total system fabricated is shown below figure 6.
4. Feasibility study

4.1. Economic feasibility
The paper is economically feasible and commercially viable and has an edge over the walking robots of current date. No doubt, there’s an extra cost for the legs against the wheels however the additional cost of the legs of robots are fully justified with the added advantage of the legged robots over the wheeled ones.

4.2. Operational feasibility
The paper involves a simple Arduino programming and hence it doesn’t attract any complication in operations. When the coding of walking algorithm is finalized, the robot could be controlled by using a remote controller with the help of the camera for navigation and the robot can be operated from a far-off place.

4.3. Technical feasibility
The paper has technical feasibility in designing and fabrication. With the advent of 3D printing technology, the robot can be designed and fabricated easily. “ABS”, the material being used has adequate strength and the vibrations generated by robots could be absorbed easily. The torque required to drive the legs of robot is estimated at 9 kg and the same can be generated from the Servo Connector proposed. Hence the paper has technical feasibility in all technical aspects.

5. Conclusion
Robotics is preferred in all industries, defense and other fields and the usage is increasing substantially on a day to day basis. Octopod with it’s on a simple walking algorithm has varied advantages and stability will become the right alternative for the wheeled robots since the challenges with other wheeled robots are overcome with this new design. Octopod will surely emerge as the convincing technology in the field of robotics and will be of great advantage in many other related fields. No doubt this paper on Octopod has its own limitations in weight and speed of the robot and leaves scope for further improvement by using more durable and less weight materials for fabrication, developing the electrical portion in a single printed circuit board and integration with artificial intelligence and computer vision. Further development in these areas will facilitate taking the octopods to the next level to meet out the emerging needs of the community and country.
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