Simulation and Intelligence System of Bio-Inspired Terrestrial Robot

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Abstract:- As we progress into the twenty-first century, technology has advanced like never before, and problems that took centuries to solve are now being solved in record time. For example, fixing an underwater damaged pipe used to be a difficult task for humans, but now we have underwater robots that can complete the task without endangering humans. Arachnoid bots, or bio-inspired spider bots, are real-life replicas of arthropods such as spiders and tarantulas that replicate spider motions and can navigate diverse terrains while remaining silent and efficient. Insects, birds, and other forms of nature have inspired micro aerial vehicles that employ wing flaps to propel themselves, which will aid us in achieving maneuverability and optimum flying efficiency. Such bots are excellent for deep forest exploration and surveying of places which are dangerous or inaccessible to humans. Another benefit is that the research might lead to the development of a new form of actuator or muscle fiber-like component, which would change the movement of all bio-inspired. This paper helps us understand the functioning, application, and advancements of bio-inspired robots, namely, terrestrial robots, aerial robots, and underwater robots which are designed and developed to overcome difficult environmental conditions that humans cannot access.

Keywords:- *Cephalothorax, Arachnoid-Bots, Micro Aerial Vehicles, Underwater Robots, Bio-Inspired Robots.*

I. INTRODUCTION

Researchers such as Beer, Quinn, Chiel, and Ritzmann, constructed six-legged walking robots in the 1990s that were directly engaged in the body cytology and neurological regulation of croton bug and stick insect locomotion (for instance, hexapod robots, via the work of the biologist Holk Cruse) Triantafyllou created a series of successful swimming robots based on research of fish swimming hydrodynamics in 1995. Franceschini's robotic vision, based on insect eyes and motion-sensitive neurons in the fly, was published in 1992, as was Webb's robotic prototype of the cricket phonotaxis in 1995 and Grasso et al in 1996. Hummer and Sahabot's robotic model of chemical targeting methods, whose polarised light compass navigation was influenced by behavioural research in the hunt for the desert ant, was first published in 1997. In 1992, Edelman's study laid the groundwork for robots whose control was based on ideas of human brain function. Spenko et al worked on a six-legged climbing robot dubbed RiSE in 2008, which like numerous other biologically inspired robots with legs, is based on the work of the biologist Robert Full. This robot uses a combination of attachment functioning inspired by feet structure and locking functioning inspired by the model of insect spines and claws to grab a vertical surface. Raibert's 1986 review of Legged Robots highlighted the leading role of energy. In 1990, Arkin built a control architecture for reactive robots from schematic theory based on an earlier work by Michael Arbib. Based on research on serpentine movement, Hirose developed various locomotives and manipulators that mimic the movements of a snake. [1],[2],[6]

Many environments containing unknown terrains of land such as narrow caves, unfamiliar territories of forests, mountainous terrains, etc., are not easily accessible to humans. Drones or Unmanned Aerial Vehicles which are used to assist human beings in a large variety of tasks in these environments, which includes surveying and mapping a specific segment of land, searching and rescue of civilians or soldiers who are injured in the field, surveillance purposes, etc, In current years, tremendous improvements have been made in the field of research and development of UAVs, leading to a revolution in the aerodynamic structure of the component [3-8]. Researchers and scientists in the present day are attempting to implement animal movement functions, revolutionizing the domain of robotics with nature-inspired components. In a bio-inspired robotic system, the fundamentals of macroscopic principles of the tissues and skeleton are converted into conventional motors, mechanical linkages, and sensors. These research innovations have enabled robots to perform in various challenging environments. The small size and the lightweight of the robot significantly limit the energy used, sensors, and onboard processing. [9-14] Additionally, the research on flapping wings of aerial robots has fascinated many researchers in the field of biology, electronics, aerodynamics, etc., Due to the aerodynamic benefits of the structure and superior maneuverability of the Micro Aerial Vehicles, the regime of a low Reynolds number will give the maximum flight efficiency and performance. [15-19] Humans first developed the urge to fly to replicate natural flying species such as insects, bats, and birds. Throughout history, humans have attempted to recreate the winged flying action of birds.

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Some of the first studies were conducted in the eleventh century. [20-24] Leonardo da Vinci studied the flying patterns of birds in 1485. He devised a machine in which the pilot lies down on a board and operates the big wings using levers operated by hand and pedals operated by foot, along with a pulley system, after concluding that humans are very heavy and feeble to fly which has wings attached to their arms. Although he is well-known for his research on bird flight, few people understand he was the first to record flying maneuvers. Birds utilize them to harvest energy from wind energy to fly for long periods. In July of 1849, the first documented usage of a UAV was for warfighting. Humans studied the behaviour of nature's flying species in great detail to improve the efficiency and optimization of drones Humans have become increasingly interested in replicating flight from all of nature's birds and insects, utilizing bionics to develop a biomimetic micro air vehicle with a small scale, great mobility, and a high-flying economy. [56-58]

II. DESIGN OF BIO-INSPIRED ROBOTS

The design of terrestrial bots is based on insects and arthropods and creatures with multi-jointed limbs. This allows for complex movements along multiple degrees of freedom. The limbs0 are controlled and actuated by SES joints which have high torque and speed characteristics while consuming low power. The concept of soft actuated SES joints is fairly new since its developing technology and solid research in this field are still lacking. Therefore, the operation and troubleshooting of this specific part are quite tedious. The power source for the above terrestrial bot would be either a lithium-ion battery of the desired specifications. The involvement of servo motors and other linking parts for movement is eliminated with the use of SES joints since these are membrane controlled have power directly delivered to it.[51]

The number of SES joints involved in the design would depend on the total weight of the design and the complexity of the components involved along with the electric wiring and chassis design.

The components to be used in the design of this bot are:

- Soft actuated SES joints: These act as the limbs of the bot helping in movement and also delivering information about the various movement parameters to auto-optimize its maneuvering abilities. [57]
- Camera module (OV7670): It is a miniature-sized, critically sensitive, image sensor module of a low voltage CMOS used for picturing and analyzing the images.
- Passive Infra-Red motion sensor module: This is useful for the detection of obstacles and hazards in environments where visibility is minimal.
- HC-SR04 Ultrasonic sensor module: This is a commonly used sensor for auditory input and since it has a wide range it can be used for proximity sensing for longer distances as well. A virtual map of the environment can be traced using this.

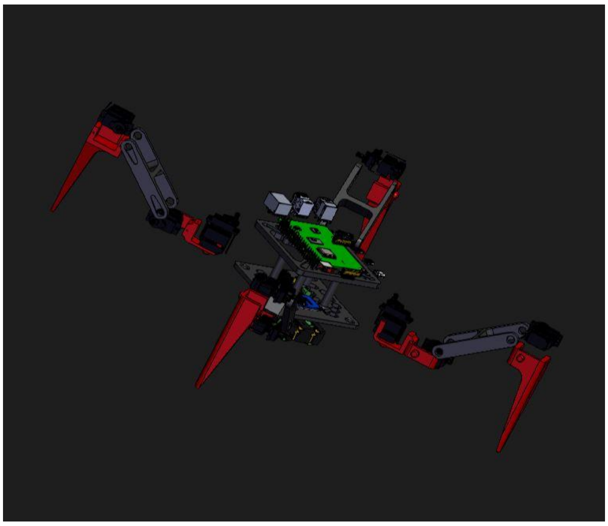

Fig 1:- 3-D design of Bio-Inspired terrestrial robot

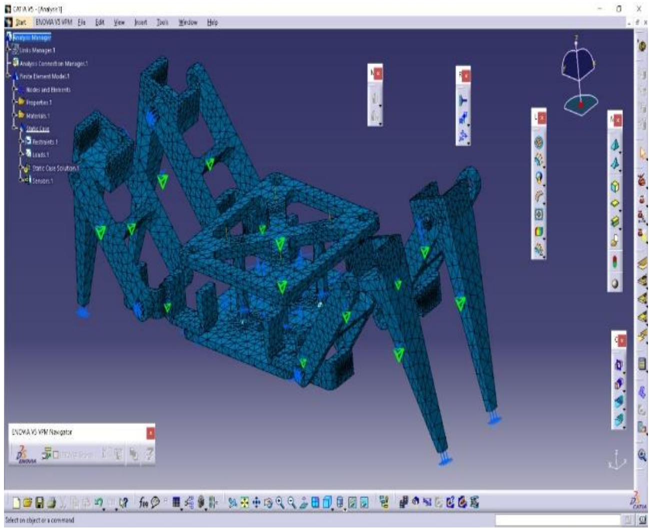

Fig 2:- Structural Analysis or the robot

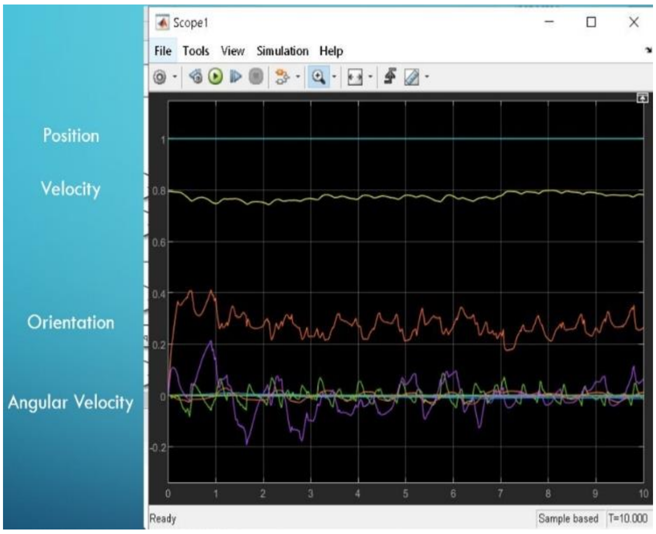

Fig 3:- Simulation Results

III. INTELLIGENT SYSTEM

The Intelligent System used in Terrestrial robots is explained below;

The intelligence system of these bots is quite complex having a microcontroller to automate and control the various functions. The exact microcontroller used here is the Arduino NANO which is a small compact, breadboard supportive board based on the ATmega328 chipset. This is powered by a mini-B USB cable. This is powered by a 6-20V unregulated external power supply via the battery. The movements and automation of traversal start with the input of the various parameters from the camera, IR, and ultrasonic modules to initiate special awareness. Once these are obtained the SES joints are actuated to initiate the movements. Since this is a new design testing, troubleshooting, and debugging are tedious tasks. The FRPC2 module acts as the wireless network link for its communication to the user.[51][53]

The Algorithm for object detection using the IR sensor is given below:

```
int analogInPin = A0;
int led =10;
int sensorValue = 0;        // value read from the pot
void setup() {
  // initialize serial communications at 9600 bps:
  Serial.begin(9600);
  pinMode(led, OUTPUT);
}
void loop() {
  // read the analog in value:
  sensorValue = analogRead(analogInPin);
  Serial.print("sensor = " );
  Serial.println(sensorValue);
  delay(200);
  if(sensorValue<80)
  {
   digitalWrite(led,HIGH);
  }
  else
  {
   digitalWrite(led,LOW);
  }}
```

The Gait Pattern and Configuration is explained below:

The quadruped robot can move statically and dynamically with stable walking. In a statically stable walk, every leg of the bot moves upwards and downwards in turn, always having at least three legs. This walk is called a creeping walk.

The walk process may be divided as eight various exercise periods. First equivalent with four legs in the stance phase at the beginning of the walking. Lift one leg to enter the swing phase. This period is called the step forward phase. From here the leg will fall and touch the ground until the next leg is lifted. This period is called the switching phase. The equivalent mechanism at this point shows the same configuration as the initial configuration but the legs contain different position parameters than compared to the beginning phase. The four legs of a four-legged robot repeat movements one by one in a fixed order from the stance phase to the swing phase to realize creep walking. While the robot is walking, the forward step stage and the shift stage alternate. The movement of four-legged robot can be described as the movement of these series equivalence mechanisms. The efficiency of this walk is low because the minimum duty factor is 75%.

Dynamic and stable gait is often used in four-legged gait and traveling robots for the following efficiencies: B. Trot walk, tempo walk, jump walk, canter walk. The study used trot. The walk cycle of this walk can be divided into four different exercise periods. When the two legs are on the same diagonal lift, the swing phase begins. After this stage, the movement enters the switching stage, where the two legs touch the ground until the other two legs are lifted. The equivalent mechanism of the switching stage has the same configuration as the initial one. The four-legged robot's four-legged robot repeats movements in pairs in a specific order from the stance phase to the swing phase, achieving fast walking. While the robot is walking, the forward step stage and the shift stage alternate. The movement of a quadruped robot can be regarded as the movement of these series equivalence mechanisms. This walking efficiency is higher than the static stable walking efficiency because the minimum duty cycle is 50%.

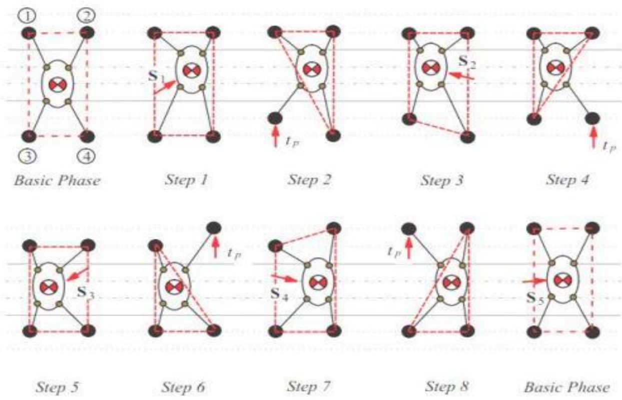

Fig 4 : Gait Configuration for static walking.

➢ *The Gait Transference is explained below:*

The four-legged robot can change the way it walks while walking on the ground. In this study, we refer to creeping and trot walking to show the conversion process between different walks of a four-legged robot. When a four-legged robot creeps, the switching phase must occur at a specific moment. At the moment, the equivalent mechanism of a four-legged robot includes four stances. In the next period, the robot can select two standing legs and move to the swing leg, changing the robot's crawling walk to trot. Similarly, you can turn a trot walk into a crawl walk while a four-legged robot is walking on the ground. Similarly, you can change other ways of walking as well.

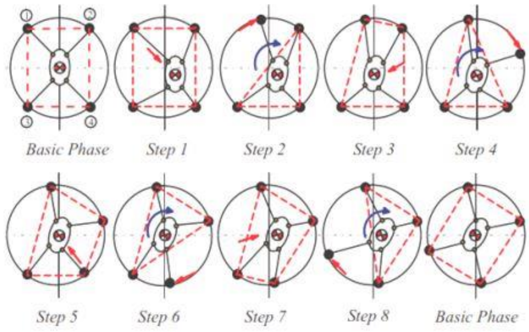

Fig 5: Gait Configuration for rotational walking

IV. APPLICATIONS

An arachnoid or a spider-like robot system will help in monitoring toxic or nuclear environments or surveying territory dangerous to humans and places where ordinary robots will be unable to move in since these bots can execute complex movements such as climbing walls up to certain inclination, rough surface traversal, etc. Location of missing items can also be done with the help of such bots. It can also be used to monitor small spaces or enclosed spots which have been sealed off due for various reasons. Since the bot contains IR and ultrasonic sensors its visibility in different terrains is very high. The presence of a camera module enables the option of recording or live transmission of visual data which is also useful for exploration purposes. Since the entire system has to be automated the complexity of the intelligence implemented in the system is high. With the assistance of Artificial Intelligence and Machine Learning, the efficiency of the movement in the bots will gradually improve which in turn will make the bots' movements more fluid with time.[46][47][48][49]

V. FUTURE ADVANCEMENTS

The future advancements of all three kinds of Bio-inspired Robots are specified below.

- To regulate smooth functioning of all sensors without margin of error.
- Sealing the important electronics components to withstand the currents of water
- To have a backup plan to retrieve the underwater robot if it stops functioning in the mid-way.
- With the concept of the latest developments such as SES joints the research involved in the project might spark ideas for future microbots since these have not been extensively used.
- The algorithm used for this bot in specific can be studied and improved on to become a standard algorithm for such ai powered bots.
- With the onset of nano chipsets and controllers, the size of the bots and the memory and functionality will greatly improve thereby improving the overall usability of the bots to a great extent.
- The research on muscle fiber-like actuators for microbots has advanced quite a bit. Shortly if such technology can be implemented onto similar robots. Then mimicking real-life creatures will be easier.

Limitations like durability underwater and in extreme conditions can be reduced with further research and development therefore these bots will find their use in extreme environments as well.

VI. CONCLUSION

These Bio-Inspired Robots will revolutionize the entire concept of robotics. There will be newer and better applications for these robots. The efficiency of these robots can be drastically increased by taking bio inspirations.

The majority of the applications are towards the Defense Sector, so by designing the body based on the shape of insects and other animals, the work can be carried out stealthily as it will be difficult for the opposition to track and catch hold the robots.

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