بسم الله الرحمن الرحيم

# “DESIGN AND FABRICATION OF SNAKE ROBOT”

A thesis submitted to the department of Mechanical and chemical Engineering (MCE), Islamic University of Technology (IUT), in the partial fulfillment of the requirement for degree of bachelor in science in Mechanical Engineering.


**Prepared By:**

Haseeb mehmood

Khalid zeyad al najjar

**Supervised By:**

Prof. Dr. Md. Anayet Ullah Patwari

**Department of Mechanical and Chemical Engineering**

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# CERTIFICATE OF RESEARCH

The thesis title “DESIGN AND FABRICATION OF SNAKE ROBOT” submitted by Haseeb mehmood (091444) and Khalid zeyad al najjar (081452), has been accepted as satisfactory in partial fulfillment of the requirement for the Degree of Bachelor of Science in Mechanical and Chemical Engineering on October, 2013.

Signature of the Supervisor

______________________

Dr. Anayet Ullah Patwari

Professor

Department of Mechanical and Chemical Engineering

# *CANDIDATE'S DECLARATION*

It is hereby declared that this thesis or any part of it has not been submitted elsewhere for the award of any degree or diploma

**Signature of the Candidate**

______________________

**Haseeb mehmood**

**Student id. 091444**

______________________

**Khalid zeyad al najjar**

**Student id. 081452**

**Department of Mechanical & Chemical Engineering (MCE)**

**Islamic University of Technology (IUT), OIC**

**Board Bazar, Gazipur Bangladesh.**

**Signature of the Supervisor**

______________________

**Dr. Md. Anayet Ullah Patwari**

**Professor**

**Department of Mechanical & Chemical Engineering (MCE)**

**Islamic University of Technology (IUT), OIC**

**Board Bazar, Gazipur Bangladesh.**

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I seek excuse for any errors that might be in this report despite of my best efforts.

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# Chapter 1

## Introduction

### Snake robot:

Snake navigator is biologically inspired mobile robots which are designed for specific purposes i.e. Navigation, sample collection, recon, voice transmissions.

Snake navigator is most useful in situations where their unique characteristics give them an advantage over their environment. These environments tend to be long and thin like pipes or highly cluttered like rubble. Thus snake bots are currently being developed to assist search and rescue teams.

Fig: Snake robot

Snake robots are developed to assist human being in different situation to avoid any fatal situations to human beings. Due to their perfect design and flexibility they can go anywhere and can do their job, they can be sent to underwater, cages, heavy grass lands, agricultural fields etc.

Snake robots come in all shapes and sizes, from meters long, firefighting snake robot to a medical snake robot developed thin enough to maneuver around organs inside a human chest cavity. Though snake robots can vary greatly in size and design, there are two qualities that all snake robots share. First, their small cross section to length ratio allows them to move into, and maneuver through, tight spaces. Second, their ability to change the shape of their body allows them to perform a wide range of behaviors, such as climbing stairs or tree trunks.

The wheel is an amazing invention, but it does not roll everywhere. Wheeled mechanisms constitute the backbone of most ground-based means of trans-portation. On relatively smooth surfaces such mechanisms can achieve high speeds and have good steering ability. Unfortunately, rougher terrain makes it harder, if not impossible, for wheeled mechanisms to move. In nature the snake is one of the creatures that exhibit excellent mobility in various terrains. It is able to move through narrow passages and climb on rough ground. This mobility property is attempted to be recreated in robots that look and move like snakes. These robots most often have a high number of degrees of freedom (DOF) and they are able to move without using active wheels or legs.

Additionally, many snake robots are constructed by chaining together a number of independent links. This redundancy makes them resistant to failure, because they can continue to operate even if parts of their body are destroyed.

Several versions of snake robots have been developed which are highly articulated devices that can use their many internal degrees of freedom to navigate tightly packed spaces. Initially designed for search and rescue operations in collapsed buildings, recently snake robots are developed for minimally invasive cardiac surgery (MICS). The MICS robots can be viewed as a teleported probe consisting of a series of links that can both drive in intercavitary spaces and assume the shape of its surroundings.

Snake robots are a new type of robots, known also as serpentine robots. As the name suggests, these robots possess multiple actuated joints thus multiple degrees of freedom. This gives them superior ability to flex, reach, and approach a huge volume in its workspace with infinite number of configurations. This redundancy in configurations gives them the technical name: **hyper redundant robots**.

With the development of snake robots many jobs can be performed without safety risks which are already been discussed.

The perfect design is that one which has more resemblance with natural snake but as natural snakes have muscles and with the help of those muscle they make their motion so to make a robotic snake there are many challenges to face and still developments are coming to optimize robotic snakes.

Snakes utilize irregularities in the terrain, such as rocks and vegetation, for faster and more efficient locomotion. This motivates the development of snake robots that actively use the terrain for locomotion, i.e. obstacle aided locomotion.

Like in our case we design snake robot to assist farmers in fuzzy fields. Like rice fields if we want to find insects which are harm full for crops we can take help of snake robots to find them through image processing, we can take a sample of sand for laboratory tests which can be stored store inside snake robots.

# Biological snake:

As we know that snake robots are naturally inspired robots. Before going to make a snake robot we should know about the real snake because by studying natural snake we can make a snake robot which resembles like real snake.

Fig : Natural snake

Snakes are elongated, legless, carnivorous reptiles. Many species of snakes have skulls with many more joints than their lizard ancestors, enabling them to swallow prey much larger than their heads with their highly mobile jaws. To accommodate their narrow bodies, snakes' paired organs (such as kidneys) appear one in front of the other instead of side by side, and most have only one functional lung.

Snakes are one of the best forms of reptiles they are power full they can move fast and can climb trees and also they can go underground, snakes can also go into deep water. These unique qualities of snakes urge engineers to develop snake robots to assist human beings.

If we be more specific about the snake and its characteristic related to robotics we should know about its different body parts which are discussed in following.

The snakes are expanded around the world and their skeletal structure allows them to adapt in wide range of environments. A few previous decades the researchers and the designers started to copy the animal motion to the mechanisms. The principle motivations of the snake locomotion are the environments where traditional machines are not applicable due to their dimensions or shapes and where the accessories like the wheels or the legs fail. Traditional wheel-based motion robots can move effective on the flat surfaces but on the rough terrain they are not very effective. However, snake-like robots can slide, swim, climb, burrow and therefore they are useful for man hard-to-reach areas, tight spaces, pipes, for inspections and medical applications, for search and rescue operations etc. Moreover, there are a lot of circumstances and working conditions which limit a human such as extreme radiation, temperature, chemical toxicity, pressure etc. But despite these aggressive conditions they have to be detected and examined in terms of safety. From aforementioned reasons there is ongoing research on robots imitating snake locomotion which are called snake-like robots. The snakes have high adaptable structure which allows them transition through the restrictive spaces. The snake skeletal structure consists of only from three kinds of bones: head, vertebrae and ribs. The snake backbone can consist of 100 – 400 vertebrae. Nevertheless, each vertebra can move only about 10° to 20° in horizontal direction and 2° to 3° in vertical direction. However, a combination of snake vertebrae can create large enough rotation. The skin of snake plays big role during its locomotion. The snakes have anisotropic friction characteristic of skin and this fact is used for motion.

# Snake skin:

The skin of a snake is covered in scales. Contrary to the popular notion of snakes being slimy because of possible confusion of snakes with worms, snakeskin has a smooth, dry texture. Most snakes use specialized belly scales to travel, gripping surfaces. The body scales may be smooth, keeled, or granular. The eyelids of a snake are transparent "spectacle" scales, which remain permanently closed, also known as brille.In the case of snakes, the complete outer layer of skin is shed in one layer.

The shape and number of scales on the head, back, and belly are often characteristic and used for taxonomic purposes. Scales are named mainly according to their positions on the body.

Snakes' eyes are covered by their clear scales (the brille) rather than movable eyelids. Their eyes are always open, and for sleeping, the retina can be closed or the face buried among the folds of the body.

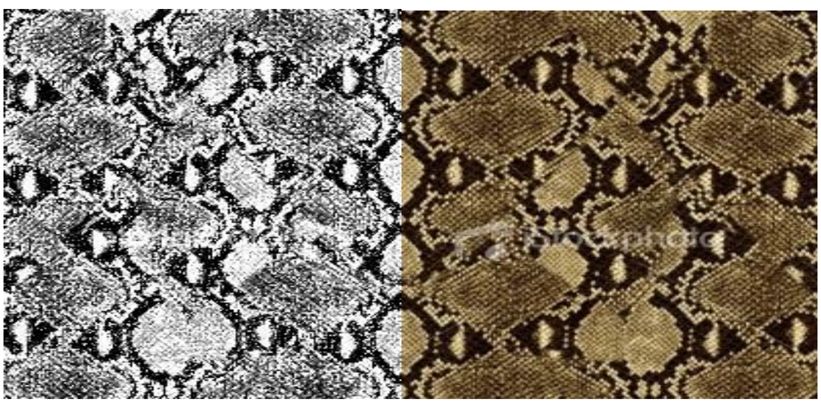


Fig: snake skin

Since snakes have no legs, the skin surface plays an important role in snake locomotion. The snake should experience little friction when sliding forwards, but great friction when pushed backwards. The skin is usually covered with scales with tiny indentations which facilitate forward locomotion. The scales form an edge to the belly during motion which results in that the friction between the underside of the snake and the ground is higher transversal to the snake body.

# Snake Skelton:

The skeleton of most snakes consists solely of the skull, hyoid, vertebral column, and ribs.

The skull of the snake consists of a solid and complete braincase, to which many of the other bones are only loosely attached, particularly the highly mobile jaw bones, which facilitate manipulation and ingestion of large prey items. The left and right sides of the lower jaw are joined only by a flexible ligament at the anterior tips, allowing them to separate widely, while the posterior end of the lower jaw bones articulate with a quadrate bone, allowing further mobility. The bones of the mandible and quadrate bones can also pick up ground borne vibrations. Because the sides of the jaw can move independently of one another, snakes resting their jaws on a surface have sensitive stereo hearing which can detect the position of prey. The jaw-quadrate-stapes pathway is capable of detecting vibrations.

The vertebral column consists of anywhere between 200 to 400 (or more) vertebrae. Tail vertebrae are comparatively few in number (often less than 20% of the total) and lack ribs, while body vertebrae each have two ribs articulating with them. The vertebrae have projections that allow for strong muscle attachment enabling locomotion without limbs.

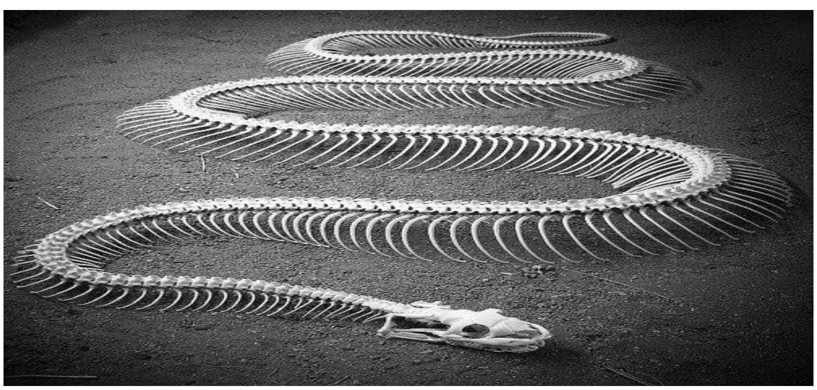


Fig: snake Skelton

The skeleton of a snake often consists of at least 130 vertebrae, and can exceed 400 vertebrae. The range of movement between each joint is limited to between 10◦ and 20◦ for rotation from side to side, and to a few degrees of rotation when moving up and down. A large total curvature of the snake body is still possible because of the high number of vertebrae.

A very small rotation is also possible around the direction along the snake body. This property is employed when the snake locomotes by sidewinding.

By studying snake Skelton we can make the chassis design of snake robot and it can be more or less like real snake.

# Snake locomotion:

The lack of limbs does not impede the movement of snakes. They have developed several different modes of locomotion to deal with particular environments. Unlike the gaits of limbed animals, which form a continuum, each mode of snake locomotion is discrete and distinct from the others; transitions between modes are abrupt.

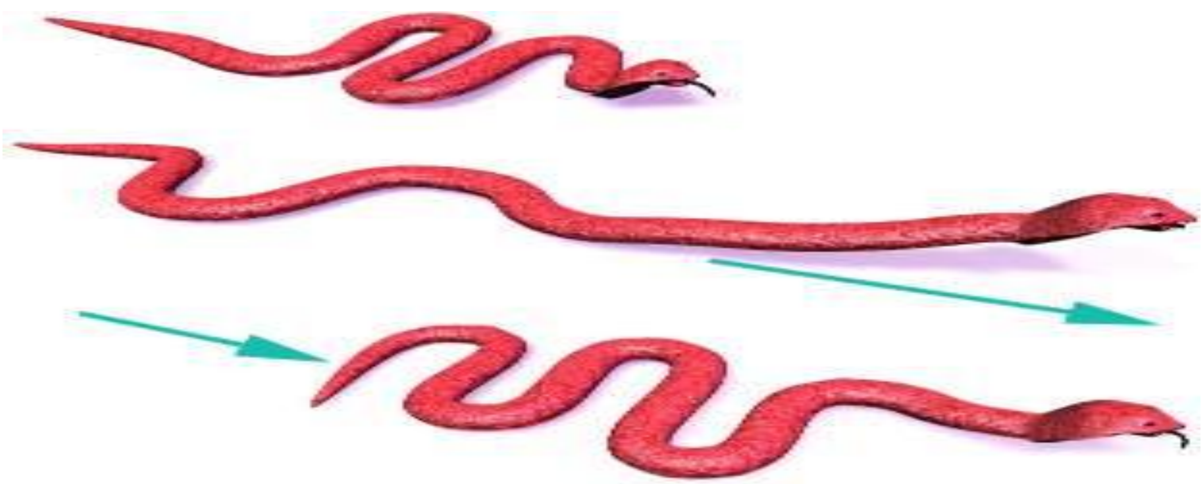


Fig: snake locomotion

Most motion patterns used by snake robots to locomote are inspired by locomotion of snakes.

In constructing snake robot, snake locomotion is the most challenging part because for locomotion we have to form some motion mechanism which when moves acts like a snake.

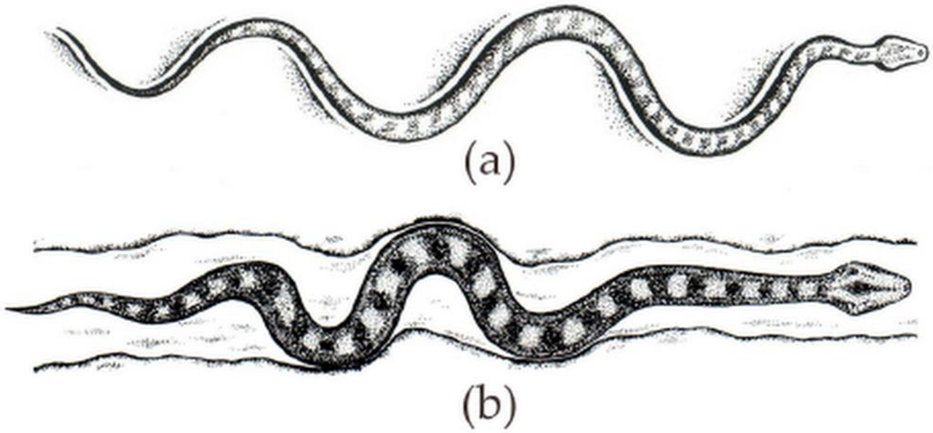
Most motion patterns implemented for snake robots are inspired by loco-motion of snakes. However, inchworms and caterpillars are also used as inspiration. The relevant motion patterns of all these creatures will be outlined in the following.

## Lateral Undulation

Lateral undulation (also denoted serpentine crawling) is a continuous movement of the entire body of the snake relative to the ground. Locomotion is obtained by propagating waves from the front to the rear of the snake while exploiting roughness in the terrain. Every part of the body passes the same part of the ground ideally leaving a single sinus-like track as illustrated in Figure (a). To prevent lateral slipping while moving forward, the snake In addition, it may use contours such as rocks on the ground to push against.

All the contact points with the ground constitute possible push-points for the snake and the snake needs at least three push-points to obtain a continuous forward motion. Two points are needed to generate forces and the third point is used to balance the forces such that they act forward.

The efficiency of lateral undulation is mainly based on two factors. 1) The contour of the ground. The more contoured the ground, the more efficient the locomotion. 2) The ratio between the lengths of the snake and its circumference. The fastest snakes have a length that is no longer than 10 to 13 times their circumference. Speeds up to 11 km/h have been observed in rough terrains.



## Concertina Locomotion

A concertina is a small accordion instrument. The name is used in snake locomotion to indicate that the snake stretches and folds its body to move forward. The folded part is kept at a fixed position while the rest of the body is either pushed or pulled forward as shown in above fig. Then, the two parts switch roles. Forward motion is obtained when the force needed to push back the fixed part of the snake body is higher than the forces acting on the moving part of the body. Concertina locomotion is employed when the snake moves through narrow passages such as pipes or along branches. If the path is too narrow compared to the diameter and curving capacity of the snake, the snake is unable to progress by this motion pattern.

## Sidewinding Locomotion

Sidewinding is probably the most astonishing gait to observe and is mostly used by snakes in the desert. The snake lifts and curves its body leaving short, parallel marks on the ground while moving at an inclined angle. Unlike lateral undulation there is a brief static contact between the body of the snake and the ground.

Sidewinding is usually employed on surfaces with low shear such as sand. The snakes can reach velocities up to 3 km/h during sidewinding

# Other Snake Gaits

Snakes also have gaits that are employed in special situations or by certain species. These are e.g. rectilinear crawling, burrowing, jumping, and sinus-lifting, skidding, swimming and climbing. The latter four, which are or may be used for snake robots.

## Snake inspired locomotion advantages

Snake-inspired locomotion provides the following advantages over traditional forms of locomotion in both animals and machines.

• Due to their elongated form and lack of legs, snakes have compact cross-sections and thus can move through very thin holes and gaps. Likewise, snake-inspired robots have much thinner cross sections than other robots with equivalent sizes and capabilities. In addition to the thinner cross section, snakes also have the ability to climb up and over obstacles that are much taller than their body height. This is done by lifting the front half of their long bodies. Similarly, a snake-inspired robot can lift its body up and over obstacles much larger than most legged or wheeled devices. These properties are very desirable when moving through complex and cluttered environments.

• Gaits used by snakes for locomotion are very stable. Because their bodies are constantly in contact with the ground at many different points, it is difficult to knock them over, especially since they have a low center of mass and do not lift their bodies off the ground much during locomotion. The form of locomotion that snakes use also relies on a large amount of contact between the ground and the posterior. This large surface area gives the snake good traction characteristics in variable environments. Whereas one wheel or leg in a traditional kind of robot may slip, the large contact surface of a snake-inspired robot would make this occurrence less likely.

• Snakes have redundant designs that rely on the same kind of joint (and structure) that is repeated many times. This means that if one joint fails, the snake can continue to locomotive. The simplicity of the design also means that the snake does not have any fragile appendages that can easily break

• Snakes are very versatile and can act as both locomotors and manipulators, as they can use their bodies to wrap around objects to grasp them. This can be seen in the climbing action across tree branches, or when a constrictor is clenching its prey. Since one structure can do both things, the need for different mechanisms to achieve different tasks is eliminated.

• Despite frictional opposition to their locomotion, snakes actually have been shown to consume a comparable amount of energy to other biological forms with similar sizes, weights, and speeds. This can be explained by the fact that snakes do not perform a significant amount of lifting of their body in their motion, and they also do not consume as much energy by moving different appendages like legged animals.

# Snake robot applications:

## ▶ Exploration

One of the applications of snake robot is to explore things where it is fatal for human beings to go. Sometimes the surface is too narrow are drastic so that a normal person can’t go there are risk of damages are more. Snake robots are sent their for exploration and get desired samples.

## ▶ Extreme terrains

They can go on extreme terrains and can perform their operation like no other robot can do. Due to their efficient locomotion they can pass by through heavy rock and can reach on higher terrains.

## ▶ Inspection

Snake robot is also sent for inspection. For example inspection of crops, inspection of pipe blockage Nuclear reactor detection

## ▶ Medical technology

Snake robots are also used for medical purpose and can assist to handle different medical tasks efficiently such as

## Robotic surgery

Robotic surgery can be perform by the help of snake robots and following are the medical surgeries which are done by using snake robot.

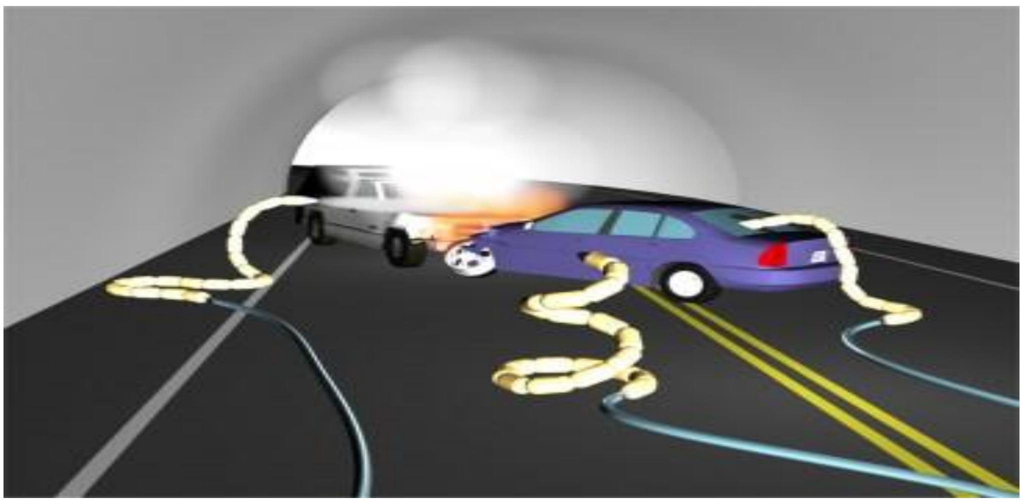
- Endoscopy
- Colonoscopy
- Neurosurgery

## ▶ Search and rescue

They are being used in search and rescue mission such as firefighting ,subsea operations.

# Tunnel fires

A Snake Fighter system permanently installed in a road tunnel can be mobilized if a fire develops inside the tunnel. The mobilized snake robots could for example perform active firefighting, provide rescue personnel outside the tunnel with live video feeds, and provide survivors inside the tunnel with oxygen and communication capabilities.



# Explosion prevention

A Snake Fighter system can be used to perform preventive efforts in environments with a high risk of explosion without the need for sending people into this environment.

# Subsea operations

By giving a Snake Fighter robot the ability to swim and move under water, it can be used for inspection and maintenance of subsea installations. These will typically be installations on the sea bed used for the production of oil and gas.

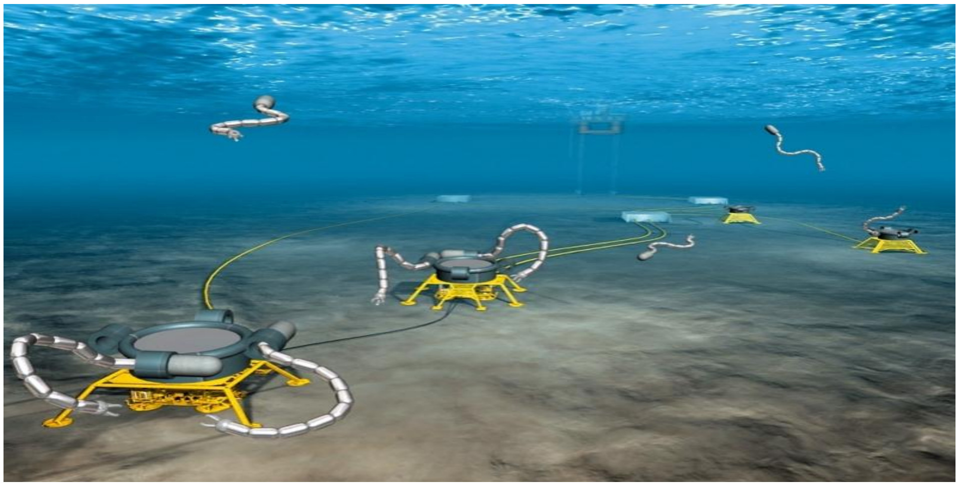


Figure 1 sub seas operations

## Search & rescue operations

A snake robot is long, flexible and slim. This makes it ideal for motion in tight and inaccessible environments. A Snake Fighter system can therefore be used to search for survivors in the ruins of a collapsed building for example after an earthquake.

## ▸ Reconnaissance

Bomb disposal and. counter terrorism

# Chapter 2

## Literature review

### Introduction:

There has been significant amount of research on SNAKE ROBOTS and their applications. Some of the important research topics and results are discussed in the following sections. The discussion however is in no way comprehensive as there is a huge volume of research literature in the field. During the last ten to fifteen years, the published literature on snake robots has increased vastly. This thesis gives an elaborate overview and comparison of the various mathematical models and locomotion principles for snake robots presented during this period. Both purely kinematic models and models including dynamics are investigated. Moreover, it's been provided an introduction to the source of inspiration of snake robots: biologically inspired crawling locomotion. Furthermore, different approaches to both biologically inspired loco-motion and artificially generated motion patterns for snake robots are discussed.

### Background of relevant research:

The first qualitative research on snake locomotion was presented by Gray (1946) while the first working biologically inspired snake-like robot was constructed by Hirose almost three decades later in 1972 (Hirose, 1993). He presented a two-meter long serpentine robot with twenty revolute 1 DOF joints called the Active

Cord Mechanism model ACM III. Passive casters were put on the underside of the robot so that forward planar motion was obtained by moving the joints from side to side in selected patterns. Since Hirose presented his Active Cord Mechanism model ACM III, many multi-link articulated robots intended for undulating locomotion have been developed and they have been called by many names. Some examples are: multi-link mobile robot (Wiriyacharoensunthorn and Laowat-tana, 2002), snake-like or snake robot (Kamegawa et al., 2004; Lewis andZehnpfennig, 1994; Lu et al., 2003; Ma, 1999; Ma et al., 2001a; Worst and Linnemann, 1996; Xinyu and Matsuno, 2003), hyper-redundant robot (Chirikjian and Burdick, 1994b) and G-snake (Krishnaprasad and Tsakiris,1994). We employ the term ‘snake robot to emphasize that this thesis deals with robots whose motion mainly resembles the locomotion of snakes.

The fastest and most common serpentine motion pattern used by biological snakes is called lateral undulation. In short, forward motion is obtained by this motion pattern by propagating waves from the front to the rear of the snake while exploiting roughness in the terrain. This has also been the most implemented motion pattern for snake robots. Note that by a motion pattern or a ‘gait of a snake robot, we mean an (often repetitive) coordinated motion of the snake robot joints employed to move the snake robot in some direction. Snakes exploit irregularities in the terrain to push against to move forward by lateral undulation. This method of loco-motion is attempted to be recreated for snake robots moving on a smooth surface by adding passive caster wheels (Ma, 2001; Ma et al., 2003a; Os-trowski and Burdick, 1996; Wiriyacharoensunthorn and Laowattana, 2002;Ye et al., 2004a) or metal skates (Saito et al., 2002) on the underside of the snake robot body. Relatively fast locomotion is obtained for snake robots with caster wheels travelling on a solid smooth surface. The dependency on the surface is important since the friction property of the snake robot links must be such that the links slide easier forward and backward than sideways for ancient snake robot locomotion by lateral undulation.

Snake robots capable of 3D motion appeared more recently (Chirikjian and Burdick, 1993, 1995; Hirose and Morishima, 1990; Lilje bäck et al., 2005; Mori and Hirose, 2002) and, together with the robots, mathematical models of both the kinematics and the dynamics of snake robots were also developed. Purely kinematic 3D models were presented in Burdick et al. (1993), Chirikjian and Burdick (1995) and Ma et al. (2003b). In such models, friction is not considered in the contact between the snake robot and the ground surface. Instead, it is assumed in Ma et al. (2003b) that a snake robot link can slide without friction forward and backward. This can be achieved by adding passive caster wheels, which introduces non holonomic constraints, to the underside of the snake robot. A different approach presented in Burdick et al. (1993) and Chirikjian and Burdick (1995) is to assume that the parts of the snake robot in contact with the ground are anchored to the ground surface. Then the other parts of the snake robot body may move without being subjected to friction forces.

Shigeo Hirose is considered one of the pioneers in snake-like robots, and his original robot called the Active Cord Mechanism (ACM) was the first functional snake-like locomotors (Figure). The purpose of Hirose's first ACM was to understand the mechanism of locomotion in real snakes. Following many studies on real snakes to ascertain the mechanisms of locomotion, Hirose developed the ACM to validate the work.

The first ACM consisted of 20 links, and had movement in only two dimensions. This means that it glided along the floor using a serpentine gait. At the core of Hirose's theories about snake locomotion was the fact that snakes produce anisotropy in friction coefficients between the lateral and tangential frictions on their ventral surface. This is what causes the propulsion in the serpentine gait. In order to realize this in a robot, Hirose placed small wheels on casters on the bottom of each link, facing in the tangential direction of the length of the robot. This resulted in a very low friction coefficient in the tangential direction, and a high coefficient in the normal direction that the snake uses to propel itself. The links were connected using joints that allow rotation to each other, and locomotion was accomplished by rotating the wheel-base mechanism back and forth. This meant that locomotion was only accomplished through shape changing, like a real snake. The entire robot weighed 28 kg, and was 2 meters long. Each joint was actuated using a servo system that consisted of a motor and a potentiometer. Control was achieved via a system whereby a command was sent to the first motor, executed, and then sent to the next motor to be executed.

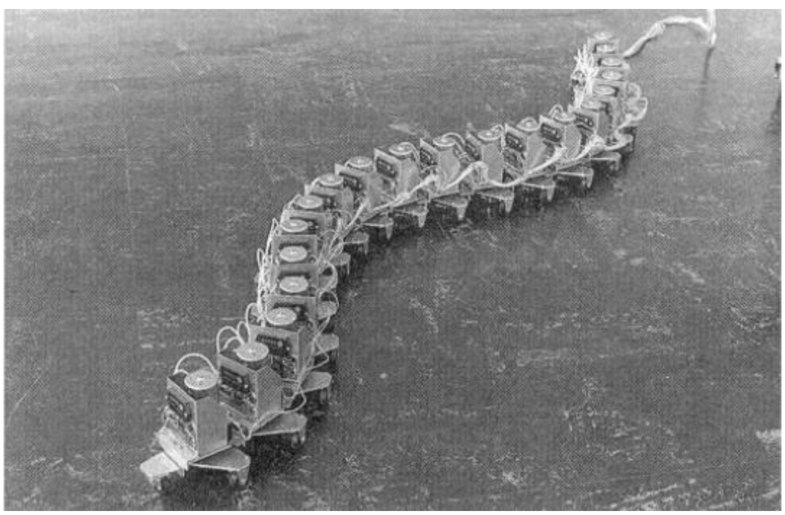


**Figure: Active cord mechanism**

Another early implementation of a snake-inspired robot was developed by Dowling at Carnegie Mellon University. Dowling developed a snake-inspired robot while studying gait generation using machine learning. Dowling took a comprehensive look at a wide range of possible technologies that could be used in snake-inspired robots, and designed a snake-inspired robot that could move in three dimensions around a servomotor actuator. Unlike the work of Hirose, Dowling's robot did not require passive wheels in order to move.

Dowling looked at the geometric design of a snake-inspired robot as it related to mission parameters. He determined the dimensions of curved and right-angle pathways that a snake could fit into as a function of link geometry and twist angle. Dowling found that the angle of motion is not as important as the link length. The link length should be as short as possible.

The mechanical design of this robot consisted of an aluminum sheet with servos mounted to it. The servos were mounted orthogonally, so that each end of the link contained an actuated revolute joint. The rotating sections were mounted directly to the servo horn, and adjacent links were attached to each other such that orthogonal servos connect to each other. A sample link can be shown in Figure 2.10. The robot contained 10 links for 20 degrees-of-freedom, and had an overall length of 102 cm. The mass of the robot was 1.32 kg, and each link had a diameter of 6.5 cm. The robot was controlled using centralized control and powered using a tether. The servos were controlled using a DCC bus and wires that runs the length of the robot. The control circuitry was located in the "head" of the snake. NiCad batteries were proposed as a power source, but external power was used in the actual implementation. Additionally, a CCD camera was mounted on the unit head.

An interesting feature of this robot was that use of "skin" was investigated to provide desirable friction characteristics. Dowling proposed covering the entire robot in a fabric or material that would provide good friction characteristics in order to propel the snake forward. Several candidate materials were discussed and evaluated

Other interesting early snake-like robots include those developed by Chirikjian and Burdick at Caltech Shan and the “Kaa” robot designed for climbing by IS robotics. An important aspect of snake-inspired robot design is the design of actuated joints. Ikeda and Takanashi of NEC developed an innovative joint for serpentine robots and manipulators. The joint was based on an actuated universal joint and was to be used in a snake-inspired robot called the “Quake Snake”.

NASA’s Jet Propulsion laboratory used a modified version of NEC’s joint in the design of their 12 degree of-freedom hyper-redundant manipulator that could be used for spacecraft applications, functioning in a crowded work space. The joint used by JPL consisted of a u-joint within a gear-head and bearing assembly. The difference between the JPL joint and the NEC joint was that the NEC joint was on the outside of the assembly.

There are several common themes in the design of many of these snake-inspired robots. Upon reviewing the designs, it can be seen that distributed control is often used, with processors and chips located in each of the links. This is done for two reasons: simplicity and modularity. In the case of the AmphiBot, the processors are located locally so that the design is modular and links can be easily added. The control system based on the central pattern generator allows for this scheme. On the other hand, in the hyper-redundant robot by Wolf et al. the processors were distributed locally so that a large number of wires do not need to travel the length of the robot.

Another common design feature in many of the robots discussed is that they rely on either a universal joint or two revolute joints in an orthogonal configuration. This is taken from the inspiration of snakes. Snake vertebrae allow for lateral and vertical twisting, and snakes locomote by using both means to move their bodies.

The robots discussed that only have motion in the lateral direction were designed for the laboratory to demonstrate gaits and control architectures. In the case of Hirose'srobots, the extra degree-of-freedom was later added.

In general, it can be seen that the majority of snake-like robots have been developed to demonstrate gaits, control schemes, and validate mathematical theory in the laboratory environment. Many of them rely on small passive wheels to locomote on smooth surfaces. In an actual search and rescue environment, the surface may not be smooth enough for the wheels to roll. In addition, many of the robots have been designed for the physical environment of the laboratory instead of the actual search and rescue environment. More recent robots, such as the AmphiBot and the ACM-R5 have been developed with ruggedness in mind with their waterproof design.

The OmniTread can be considered the most functional robot for search and rescue application; however, it illustrates another major drawback in snake-like robot design. The design of the Omni Tread contains many parts and is complicated from a mechanical standpoint. Considering that each bellows requires 2 valves to actuate, the entire design has 48 different valves for actuation. Since the actuation of the bellows requires air lines, a manifold is built into the chassis. The shape of the chassis is so complicated that it must be built using the SLA process. The drive train also requires man parts including worm gears and universal joints. The Omni Tread is not alone in its large part count. Looking at Figure 2.10, it can be seen that assembling just one link of Dowling's robot would require the relative placement of 9 parts and more than 16 screws. Large part counts, large number of assembly operations, and specialized manufacturing processes would make these snake inspired robots costly to produce.

The Scandinavian-based Foundation for Scientific and Industrial Research ("SINTEF") thinks that it might be able to offer an alternative to Martian exploration than traveling by wheeled rovers. In order to get into tight places and move around obstacles, SINTEF researchers are trying to see if snake-like robots might be a good exploration option.

Snake robots may one day play a crucial role in search and rescue operations and fire-fighting where it may either be too narrow or too dangerous for personnel to operate. Properties such as high terrain ability, redundancy, and the possibility of complete sealing of the body of the robot, make snake robots very interesting for practical applications and hence as a research topic. During the last ten to fifteen years, the published literature on snake robots has increased vastly. However, no thorough review of the theory presented in this period regarding mathematical modeling techniques and locomotion of snake robots has been found.

# Concept of snake robots:

In desigining a robot many factors came across such as size, power, and weight. If we see other type of nature inspired robots we will find some difficulties in design, weight balance and other mechanical factors, for example desigining a four legged robot is a challanginging job where a lot of calculation are required to create weight balance and there is another problem that we need more power to send these type of robots to higher terrains, this encourages us to design a such naturally inspired robot which can help us in more effective way such as snake robot.

As snake robot a snake-arm robot is a slender hyper-redundant manipulator. The high number of degrees of freedom allows “snake” along a path or around an obstacle.

Other features which are usually (but not always) associated with snake robots:

- Continuous diameter along the length of the arm.
- Easy to move through thin holes and gaps.
- Able to climb up and over obstacles.
- Versatile and can act as both locomotors and manipulators.

- Stable gaits for locomotion.
- Self-supporting
- Multiple degree of freedom
- Ease in obstacle detection
- Stability
- Terrainability
- Good traction
- the plastic deformation of the soil
- High redundancy

# Different designs of snake robot:

There are various designs are developed for snake robot depending upon their nature of use.

Some robots are designed to go inside pipes some are developed to go underwater and some are designed for inspections in nuclear plants.

Following are the classification of snake robot design.

- Passive wheels
- Active wheels
- Active treads
- Robot based on undulation using vertical waves
- Undulation using linear expansion

- ## Passive wheels:

The first category of snake-inspired robot designs to be covered is arguably the most well-known: snake-inspired robots with passive wheels. The lateral undulation gait by means of passive wheels is characterized by effectiveness but limitation in various kinds of applications as well. The passive wheels generate friction characteristics of snake skin and they serve as obstacles for snake-like robot forward motion.

### 1. Design:

Place small wheels on casters at the bottom of each link, facing in the tangential direction of the length of the robot.

### 2. Function:

Using passive wheels to resist lateral movement of the robot's segments

### 3. Locomotion:

Lateral undulation

### 4. Examples.

- ACM family
- Gavin Miller's robots
- Amphibot


**Fig:** Passive wheel type robot

# Active wheels:

The second snake-inspired robot category encompasses robots that utilized active driven wheels to provide propulsion for the robot. However, the robot designs still exhibit snake-like motion due to the multi-segment configuration. One of the main advantages of using powered wheels is ability to simulate snake-like motion without a large number of segments. Powered wheels also generally are more able to deal with non-smooth terrain types. Although the introduction of powered wheels adds additional flexibility in terms of active DOF, it also adds additional complexity to the robot, which now has to actively control these additional DOF and coordinate them with the rest of the actuated joints during global movement.

- ## Motivation

Main propulsion of a moving snake came from hundreds of tiny scales that are on the bottom side of the snake

- ## Design

Each unit is supported by an independently powered single wheel, which is driven by motors

- ## Locomotion

Rectilinear motion

- ## Examples

Koryu-II

ACM-R4


# Active treads:

The need for natural disaster relief efforts, such as search and rescue operations following a major earthquake, had inspired the design of several snake-inspired robots which utilized powered treads or crawlers to traverse extremely rough terrain. Considering that it was very difficult and dangerous to creep into the debris to find victims, robots which could maneuver in this environment in order to find these victims with TV cameras and microphones were highly desired. Such robots which combined the capability of treads with the advantages of snake-inspired robots would be able to navigate small, tight openings within the debris and locate and assess the condition of possible survivors, and allow rescuers to focus their effort more efficiently in extremely time critical scenarios.

- ## Design

Utilize powered treads to traverse extremely rough terrain

- ## Function

Increase contact area

Provide propulsion

- ## Locomotion

Rectilinear motion

- **Examples**
    I. IRS soryu
    II. OmniTread OT-4
    III. JL-I
    IV. Moira 2





# Robot based on undulation using vertical waves:

Although the robots presented thus far mimicked snake-inspired locomotion, none of these robots advance using pure undulation or the changing of the robot's position due entirely to changes in body shape (e.g., wheels, treads or legs are not used). However, there exist a number of snake-inspired robot designs which do utilize pure undulation, in particular rectilinear motion, to mimic snake-inspired motion.

# Design

Modular robots.

Each module consists of a single servomotor, which provided the torque to move and maintain angles.

# Function

Using pure undulation in body shape to generate waveforms.

# Locomotion

Lateral undulation, Sidewinding, Concertina, Rectilinear...

# Examples

- CMU’s snake robot
- NASA’s snakebot
- M-TRAN III


**Fig**: Robot based on undulation using vertical waves

# Undulation using linear expansion:

Rectilinear motion can also be achieved by linear expansion and contraction of the robot’s body to form a gait similar to the gaits utilized by real snakes. In rectilinear motion demonstrated by snakes, lateral bending of the body and lateral resistances do not contribute to the motion in contrast to the other locomotion modes. Instead, waves of muscular contraction travel through the snake in forward direction. These muscular contractions are capable of producing tensions between the vertebral column and the ventral skin and thus propel the ventral surface forward against frictional resistance.

# Motivation

Muscular contractions are capable of producing tensions between the vertebral column and the ventral skin and thus propel the ventral surface forward against frictional resistance

# Design

Modular robot

Contracting and expanding

Connecting and disconnecting

# Locomotion

Rectilinear motion

# Examples

Crystal robot

Telecubes

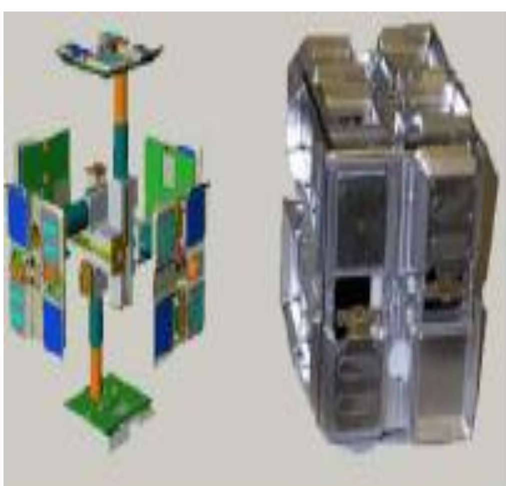



**Fig:** Undulation using linear expansion

There are many other snake robots models which are already developed and there are many ideas to develop more innovative designs to increase its working capabilities to its optimum level.

Those robots models which are more close to nature can give better results so it is suggested to make a robot which is more close to nature. So in the next chapter we will discuss about the modeling of snake robot y considering different parameters.

# Chapter 3

## Design of snake robot

## 3.1. Aims and Objectives

The objective of this project is to design a snake-like robot, which can either move by making decision itself in an unknown terrain (inspection) or move remotely with the assist of camera. Besides that, we are also required to program the snake-like robot so that it can move similar as the biological snake.

The project is classified which are the:-

- Mechanical structure of robot
- Electrical part
- Programming part

### 3.1.1. Mechanical structure of robot:

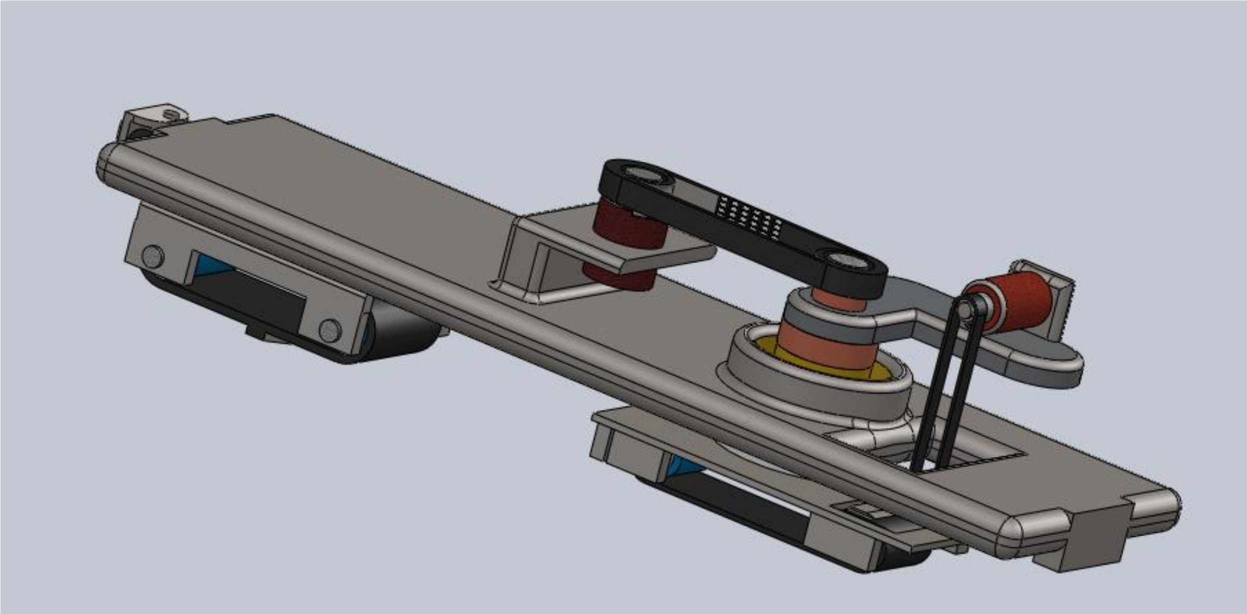
In this section our main focus was to develop such a mechanical structure that can assist us in achieving our objectives in effective way. We did study on kinematics of robot, which tell us the geometrical aspects of motion.

Once we finalize our design study we started to construct our robot to test wethr this structure is fulfilling our objectives or not.

## 1. CAD designing:

We design our robot by using designing software SOLID WORK

In solid works we design each and every component of robot and then we assembled whole robot in SOLID WORKS to check the design features. In our first design which is shown below



In this design we used rollers with conveyer belts which are driven by a servo motor. Another motor we used to provide multiple degrees of freedoms. When we tested this design there were several draw backs which leads us to develop new design.

Its major drawback was the motion mechanism. When other 2 bodies were connected to main body it was not making exact the same motion mechanism which we develop. The main reason behind this was that we connected the motion mechanism links to the roller shaft which is mounted on front part of body. When we rotate that shaft the front part rotates 45 degree but the second and third cart rotate only 15 to 20 degree. Which leads to failure of this design.

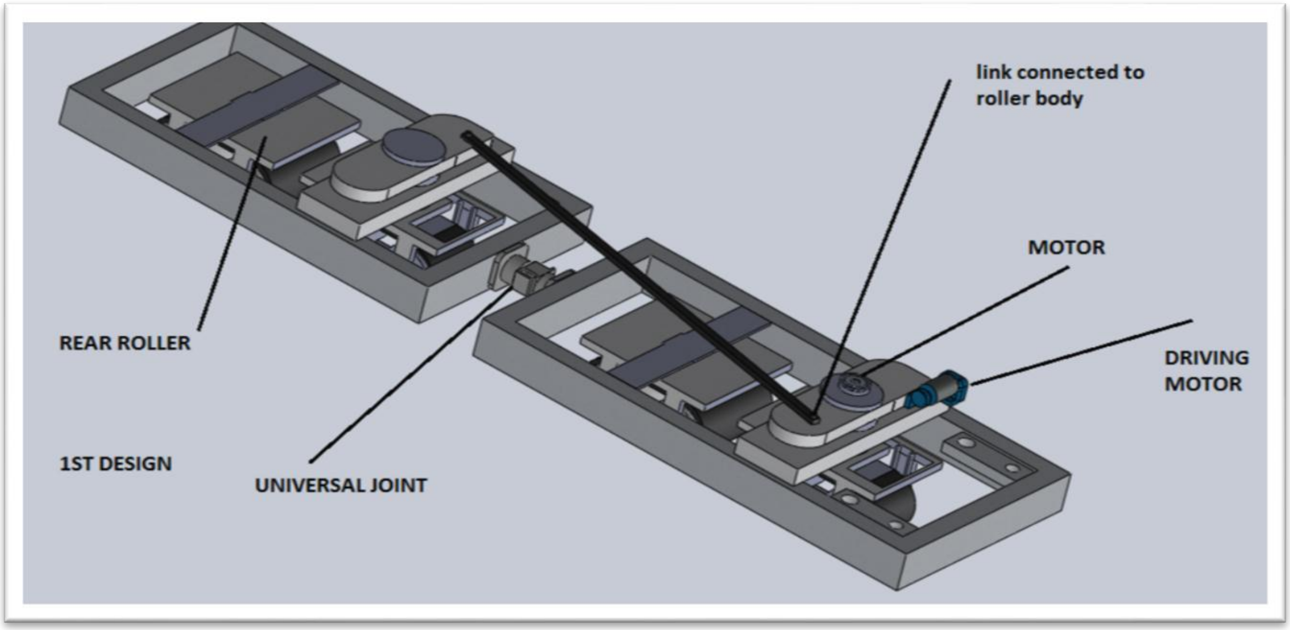



**Fig: first design of snake robot.**

Another drawback of this design was to join bodies together. We tried different mechanisms but when we start motion of the links the bodies struck to their positions and hamper whole motion mechanism. And even if tires move and motion mechanism works but the upper body remains stationary only tires make motion like snake. This was another reason to change our design because our design was not up to our requirements.

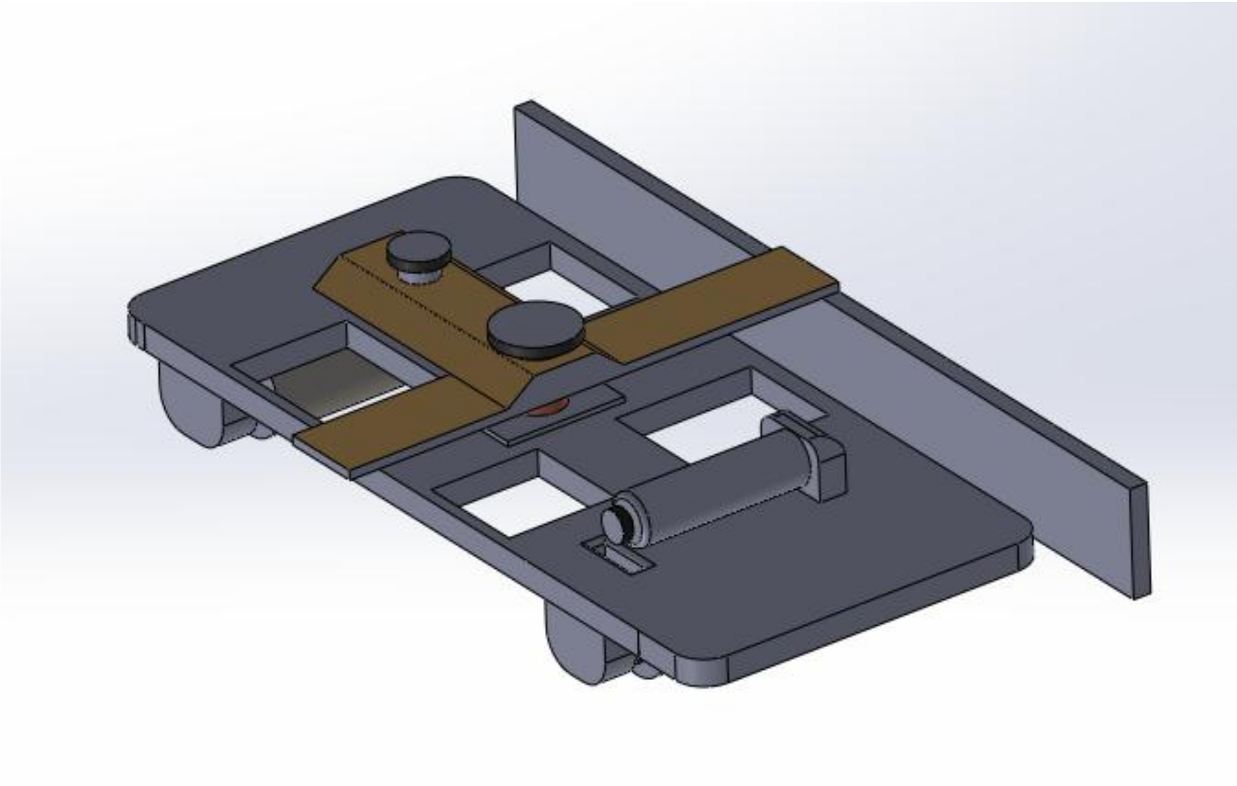


**Fig: 1st design of snake robot.**

# 2. Modification in CAD design:

By considering all faults we redesign our robot and change few things in previous design which gives better results. Following were the modifications were made in design.

a) We shifted all motion mechanism from roller shaft to body.

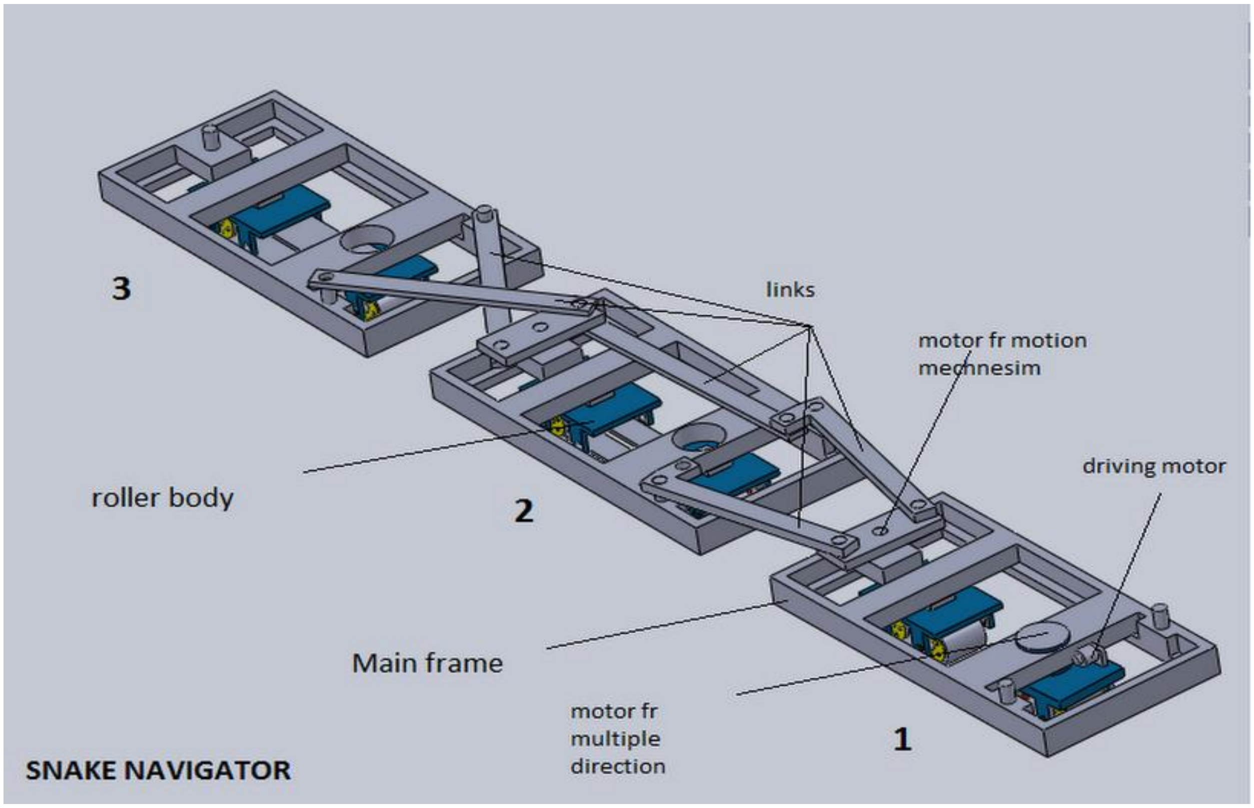
b) We fixed 1st body and allow other bodies to make relative motion of snake with respect to first body.

c) We connected links to body instead of connecting with roller body shaft of second cart.

d) We put three stepper motors; two motors were connected in first and second body to make motion like snake. Those motors works in such a way that when first motor rotates 45 degree clockwise then second motor will rotate anticlockwise. This makes a complete motion like snake. Another motor we used in front of first cart of robot to give multiple direction to move.

e) As links were connected directly with bodies so the problem of linking carts was solved. In this design no additional joints were used to hold body's together.

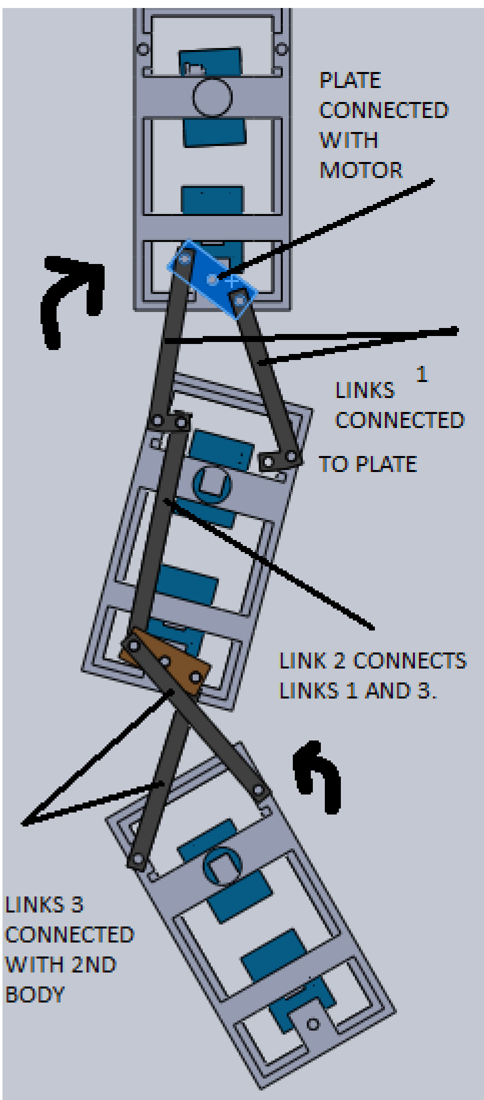
f) The whole modified design is shown in figure

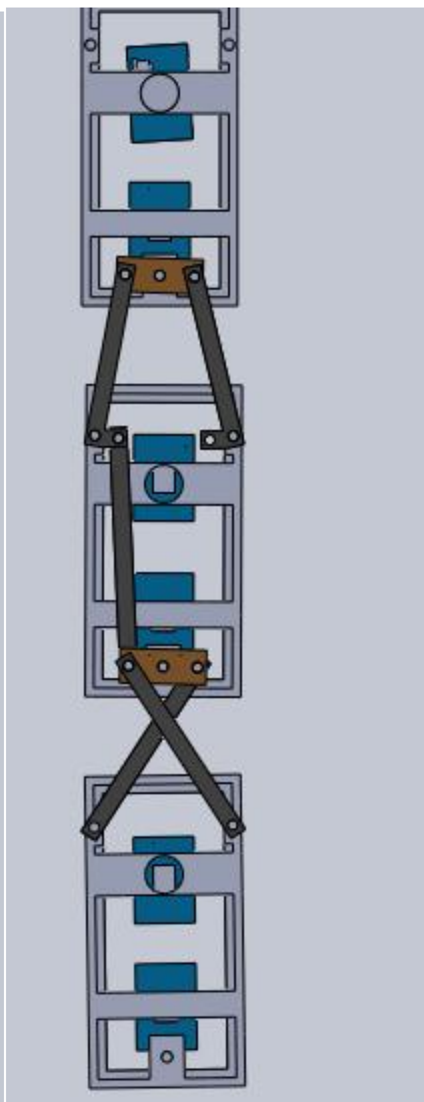


# 3. Design simulation:

After the completion of design and removal of all drawbacks we made our whole model in SOLID works and simulate it.

We simulated its motion mechanisms through SOLID WORKS motion study which gives us the results we want. During motion study we put some imaginary motors and program them according to mechanism and then we run those motors in SOLID WORKS. Those links and others joints were working according to proposed mechanism.





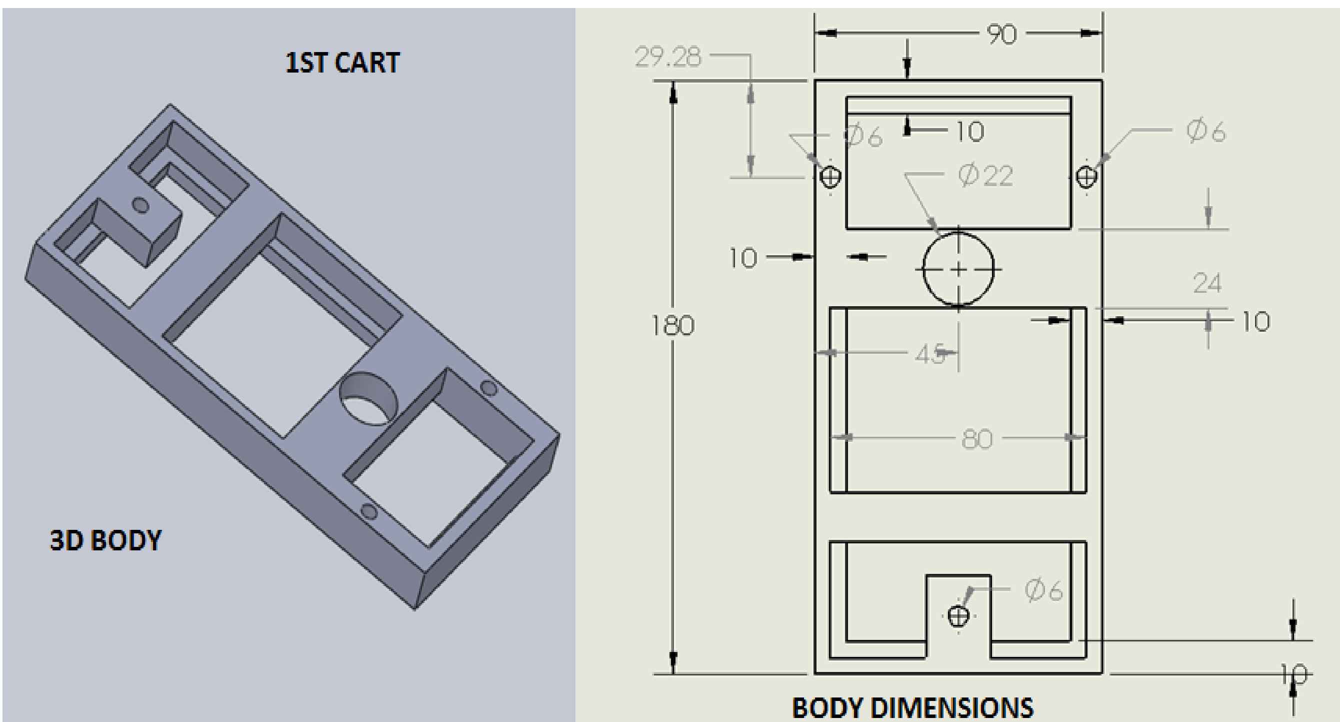
# 4. Mechanical components of snake robot :( Dimensions)

For mechanical part, the body or other mechanical parts can suit to the locomotion of the snake-like robot have to be ensure, so that it can move in 2- axis (the xy-plane), able to overcome the obstacle and move on uneven surface, and the weight of the chosen material is important for the locomotion as well.

Mechanical components with dimensions are shown below:

## 1. MAIN BODY:

We made three bodies according to given dimensions.



## 2. ROLLER AND ROLLER BODY:

In this robot we used rollers instead of tires. There is an advantage of rollers with conveyer belt over tires. Tires can struck in sand or thick grass but roller can move easily because of use of conveyer belts. Another advantage of roller is that it gives better traction than tires and avoids slip during climbing on high terrains. Roller and roller body are shown in figure with their dimensions.

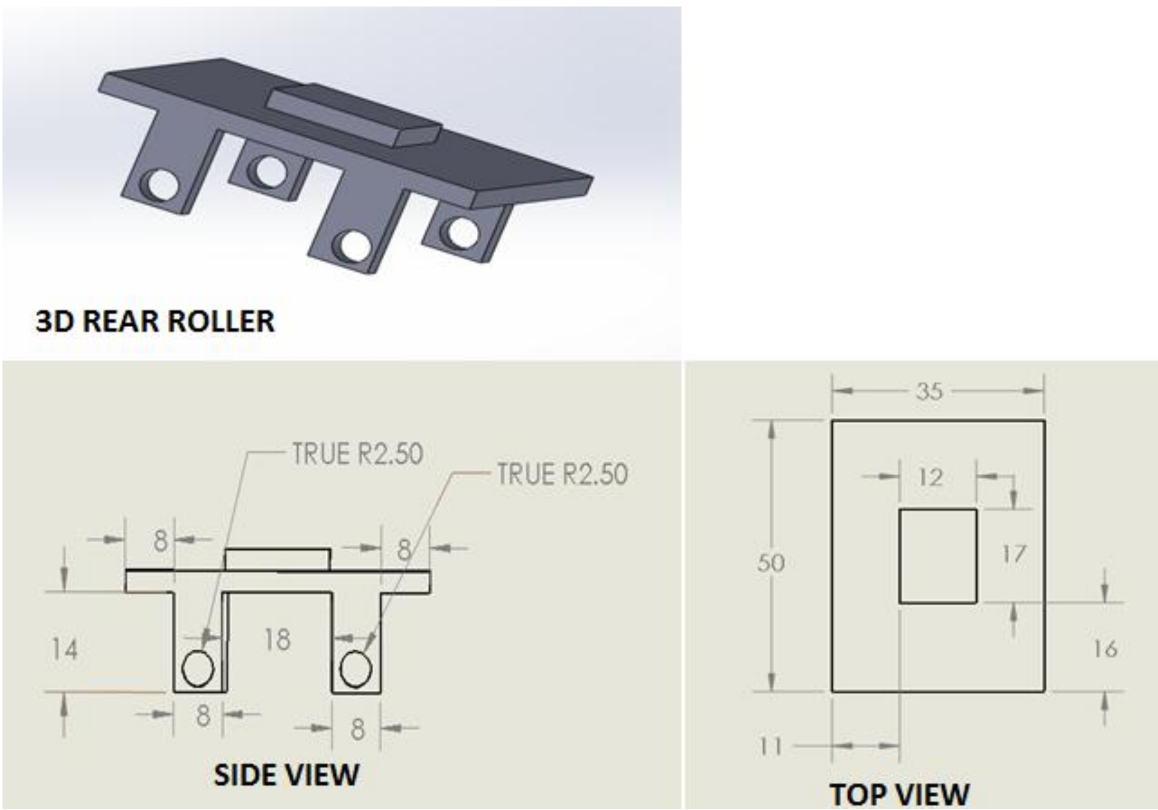
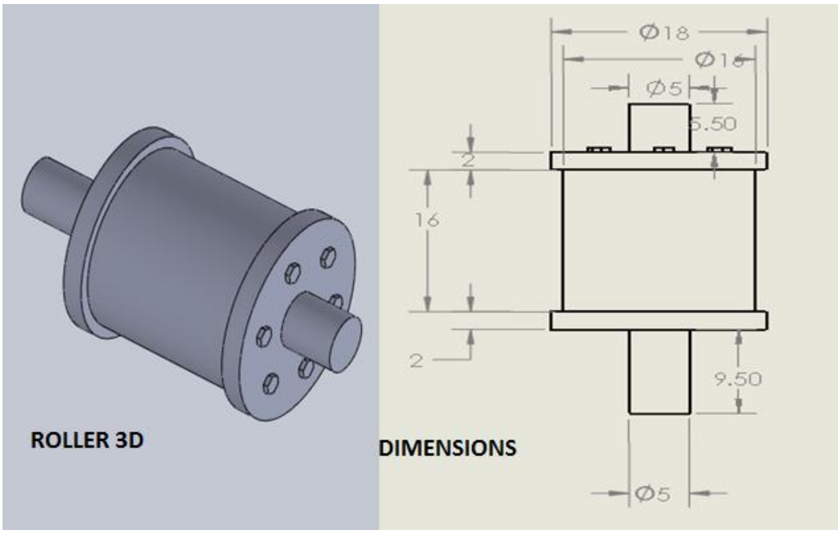



**Fig: Roller body**




# Fig: Roller

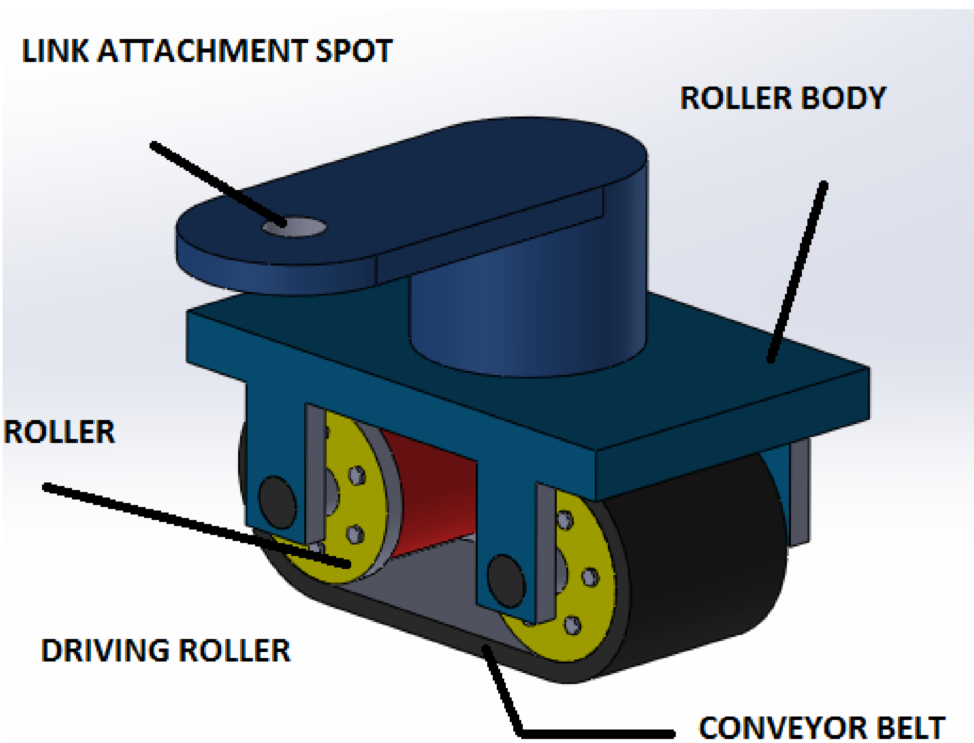



**Fig: complete assembly of roller with shaft**

# 3. Motion mechanism links:

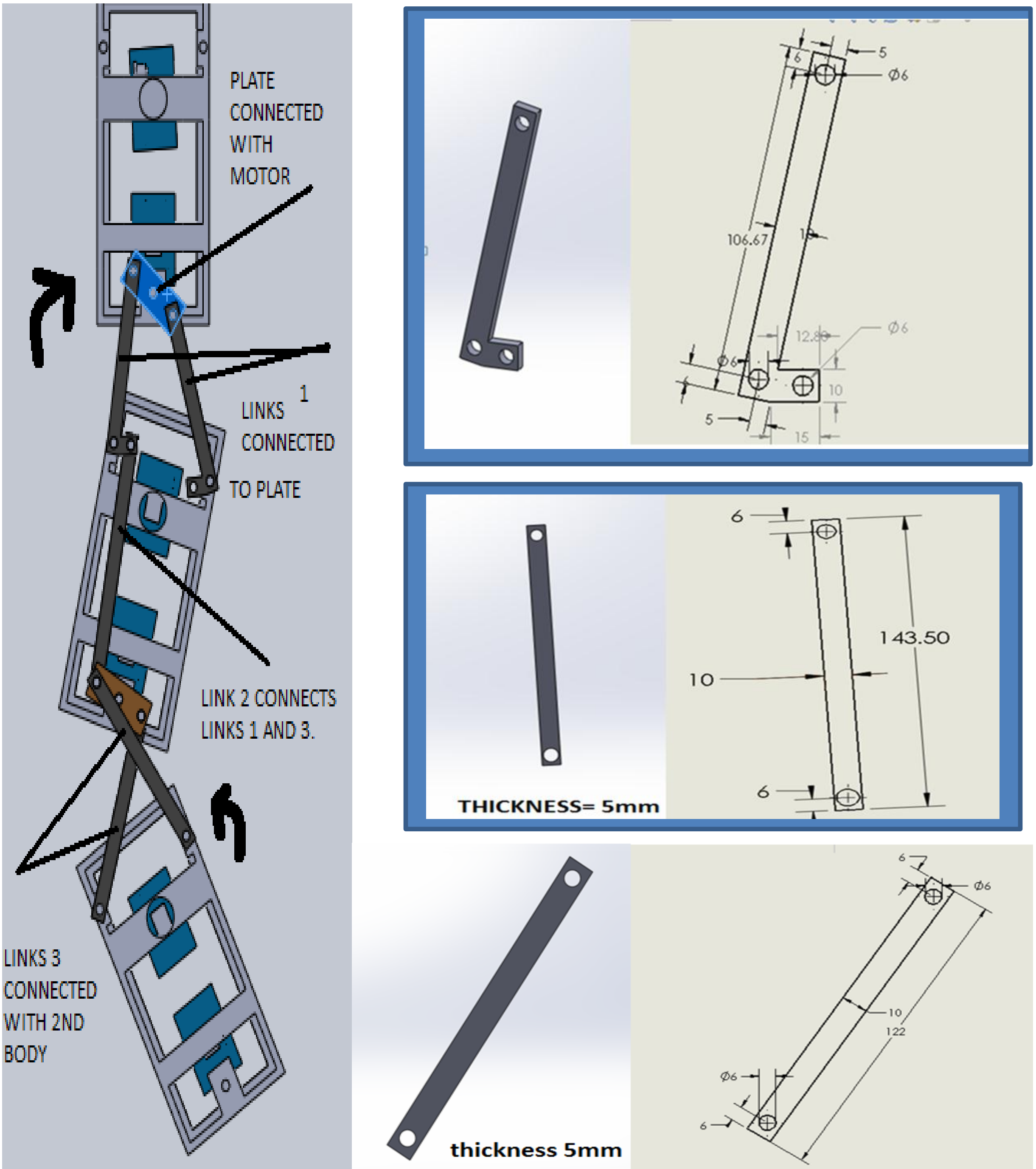



Figure 2 links

## 3.1.2. Electrical components of snake robot:

in order to drive our robot we need several electrical components. Electrical motors are used to drive snake robot. Following are the list of electrical components which are used to drive and control snake robot.

- Motors (d.c and servo)
- Battery
- Microcontroller
- Circuit board and other small electrical components.( resistance, diode,capicator etc.)

## 1. Electrical motors:

For snake robot two type of motors were used.

- D.C motor
- Servo motor

## I. D.C motor:

In snake robot d.c motor was used to drive the robot. A DC motor is a mechanically commutated electric motor powered from direct current (DC). The stator is stationary in space by definition and therefore the current in the rotor is switched by the commutator to also be stationary in space. This is how the relative angle between the stator and rotor magnetic flux is maintained near 90 degrees, which generates the maximum torque.

DC motors have a rotating armature winding (winding in which a voltage is induced) but non-rotating armature magnetic field and a static field winding (winding that produce the main magnetic flux) or permanent magnet. Different connections of the field and armature winding provide different inherent speed/torque regulation characteristics. The speed of a DC motor can be controlled by changing the voltage applied to the armature or by changing the field current. The introduction of variable resistance in the armature circuit or field circuit allowed speed control. Modern DC motors are often controlled by power electronics systems called DC drives.d.c motor is shown in figure.

Figure: D.C motor

## II. Servo motor:

Two servo motors were used in robot. These servo motors were installed in first and second cart of robot to make the snake like motion (motion mechanism).

Servomotor is a rotary actuator that allows for precise control of angular position, velocity and acceleration. It consists of a suitable motor coupled to a sensor for position feedback. It also requires a relatively sophisticated controller, often a dedicated module designed specifically for use with servomotors.

Servomotors are not a different class of motor, on the basis of fundamental operating principle, but uses servomechanism to achieve closed loop control with a generic open loop motor.

Servomotors are used in applications such as robotics, CNC machinery or automated manufacturing. Most modern servomotors are designed and supplied around a dedicated controller module from the same manufacturer. Controllers may also be developed around microcontrollers in order to reduce cost for large volume applications.

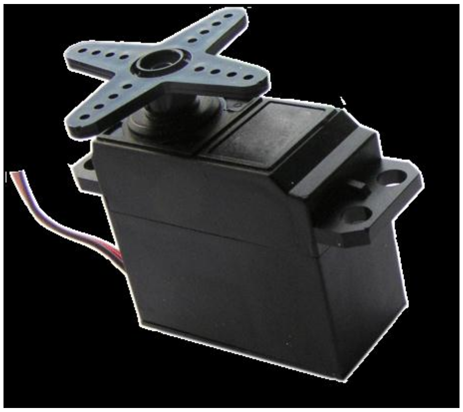


**Figure: servo motor**

## 2. Battery:

Small battery is used to provide electrical current to electrical devices which are used in snake robot and keep them running for sometime.

An electric battery is a device consisting of one or more electrochemical cells that convert stored chemical energy into electrical energy

Each battery consists of a negative electrode (anode) that holds charged ions, a positive electrode (cathode) that holds discharged ions, an electrolyte that allows ions to move from anode to cathode during discharge (and return during recharge) and terminals that allow current to flow out of the battery to perform work.

Batteries are either primary (single-use or "disposable") that are used once and discarded or secondary (rechargeable batteries) that are discharged and recharged multiple timesBatteries are made from many materials including various metals, carbon, polymers and even air. The most common are lead-acid batteries used in vehicles and lithium ion batteries used for portable electronics. Batteries come in many shapes and sizes, from miniature cells used to power hearing aids and wristwatches to battery banks the size of rooms that provide standby power for telephone exchanges and computer data centers.


Figure: Robot battery

# 3. Microcontroller:

A microcontroller (sometimes abbreviated µC, uC or MCU) is a small computer on a single integrated circuit containing a processor core, memory, and programmable input/output peripherals. Neither program memory in the form of NOR flash or OTP ROM is also often included on chip, as well as a typically small amount of RAM. Microcontrollers are designed for embedded applications, in contrast to the microprocessors used in personal computers or other general purpose applications.

Microcontrollers are used in automatically controlled products and devices, such as automobile engine control systems, implantable medical devices, remote controls, office machines, appliances, power tools, toys and other embedded systems. By reducing the size and cost compared to a design that uses a separate microprocessor, memory, and input/output devices, microcontrollers make it economical to digitally control even more devices and processes. Mixed signal microcontrollers are common, integrating analog components needed to control non-digital electronic systems.

Some microcontrollers may use 4-bit words and operate at clock rate frequencies as low as 4 kHz, for low power consumption (single-digit mill watts or microwatts). They will generally have the ability to retain functionality while waiting for an event such as a button press or other interrupt; power consumption while sleeping (CPU clock and most peripherals off) may be just Nano watts, making many of them well suited for long lasting battery applications. Other microcontrollers may serve performance-critical roles, where they may need to act more like a digital signal processor (DSP), with higher clock speeds and power consumption

Figure: microcontroller

# 3.1.3. Programming part:

For programming part, programming on the snake-like movement for the snake-like robot need to be done, and with the vision assist of the camera, the snake-like robot will able to decide the possible solutions to overcome the obstacle that it face, and also able to respond to the feedback of the controlling sensors like angle sensor.

In Programming part, the scopes are set as below:-

-The snake-like robot able to provide snake-like locomotion.

-The snake-like robot can make the decisions itself when facing problems (obstacles).

-The distance can be detected with the assist of sensors.

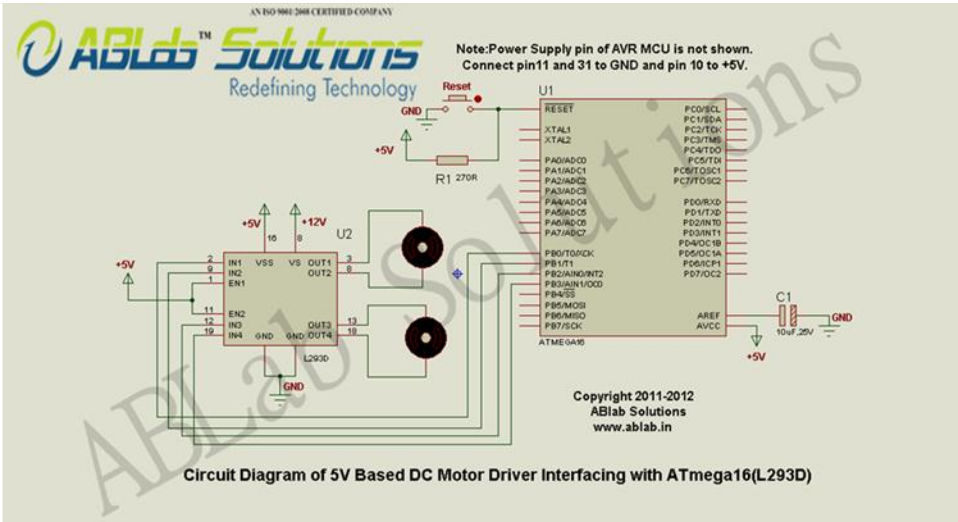
-The snake-like robot can lift at a certain height so that it can climb stair or climb over the obstacles.

-The snake-like robot can remotely control by the user.

**1. Code to run a DC motor at constant speed :**

```
#include<avr/io.h>                    //library file
#define F_CPU 100000            //set the microcontroller frequency
#include<util/delay.h>
 Void main (void)
{
 DDRB = 0x0f                                  //portb is declared as output
      While (1)
     {PORTB = 0x0A;                        //snake will move forward
        _delay_ms (1000);
        }
```

# 1. Circuit configuration




# 2. Obstacle detection mechanism:

To detect obstacle we have used proximity sensors in snake robot.

# Proximity sensor?

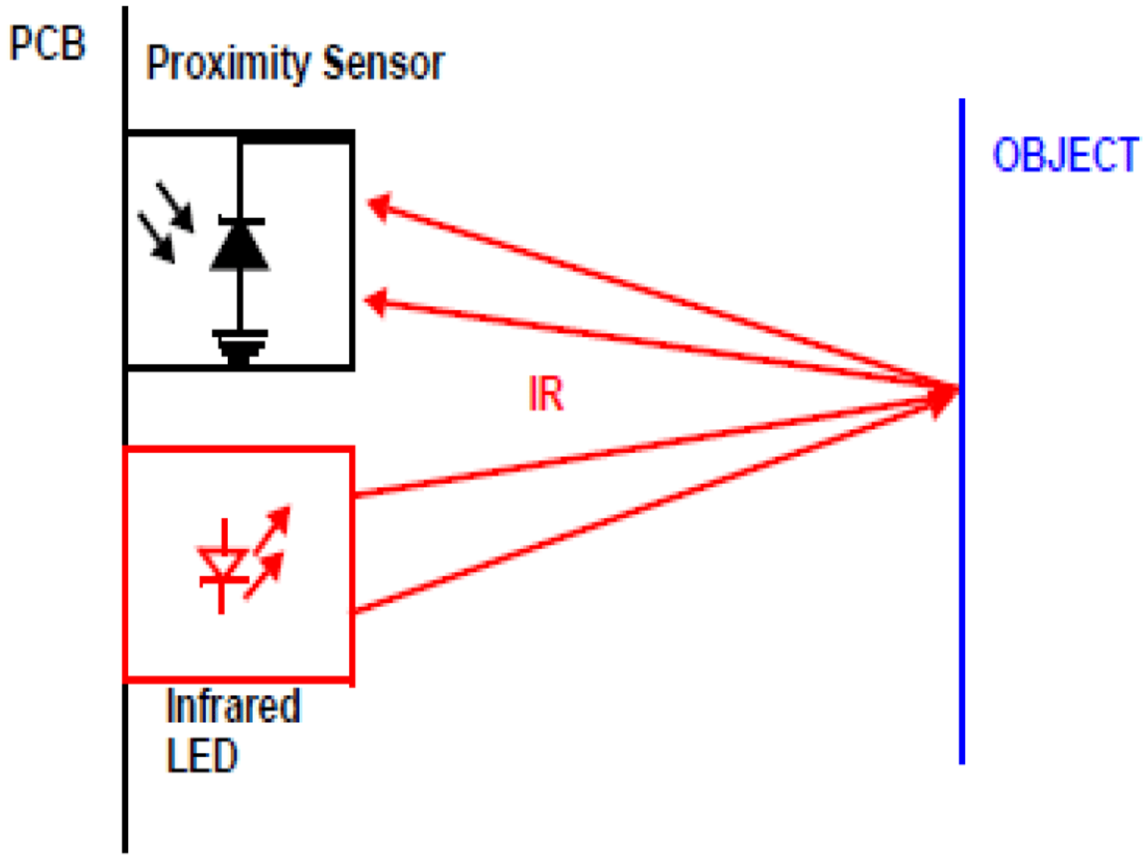
A proximity sensor is a sensor able to detect the presence of nearby objects without any physical contact.

A proximity sensor often emits an electromagnetic field or a beam of electromagnetic radiation (infrared, for instance), and looks for changes in the field or return signal. The object being sensed is often referred to as the proximity sensor's target. Different proximity sensor targets demand different sensors. For example, a capacitive photoelectric sensor might be suitable for a plastic target; an inductive proximity sensor always requires a metal target.

The maximum distance that this sensor can detect is defined "nominal range". Some sensors have adjustments of the nominal range or means to report a graduated detection distance.

Proximity sensors can have a high reliability and long functional life because of the absence of mechanical parts and lack of physical contact between sensor and the sensed object.

In our robot we installed proximity sensor in front cart whose task is to detect obstackles and change the direction of motion of snake robot. Following fig will show how a proximity sensor works.




## Figure 3 working of proximity sensor

# Control method:

The snake-like robots use gait patterns according to the environment in which they locomote. As basic definition we can say that motion is cyclic model of an internal shape changes which lead to the specifically gaits. In general, the control methods used to snake-like robots motion can be divided into three categories: sine-based approaches, model based approaches and central pattern generator (CPG) based approaches

**Sine-based approaches**

Sine-based approaches use sinusoidal functions to generate the reference signals for the actuators. By means of this kind of control individual segments joint angles vary sinusoidal.

**Model based approaches**

Model based control covers a variety of different types of controls that incorporates mathematical models (kinematic or dynamic model of a snake-like robot). Modeling parallel systems typically can result in combined constraining algebraic and differential equations. Model based control utilizes a model and knowledge of the quasi-static value of the disturbance to compute the optimal values. Since no models in practice describe the process exactly, the hereby found optimum will be an estimate of the real optimum. Estimation errors can be caused by several factors:

· Errors in the model structure

· Uncertain parameters

· Unmeasured disturbance influencing the process

· Unknown state variables

· Measurement noise

Model based approaches make it possible to analyze the overall systems and determine the optimal parameters and the most efficient gaits, as well as allowing necessary feedbacks. This means, they are quite suitable for designing controllers. However, synthesis controllers cannot be always manipulated online and the accuracy of developed models might sometimes decrease due to unexpected changes in the environment or uncertainty of the model

**CPG approaches**

Many organisms exhibit repetitive or oscillatory patterns of muscle activity that produce rhythmic movements such as locomotion, breathing, chewing and scratching. The neuronal circuits that give rise to the patterns of muscle contractions which produce these movements are referred to as central pattern generator, or CPG. In the other words, CPG can be defined as neural networks that can endogenously produce rhythmic pattered outputs or as neural circuit that generate periodic motor commands for rhythmic movements. All rhythms require:

· Two or more processes that interact such that each process sequentially increases and decreases

· That, as a result of this interaction, the system repeatedly returns to its starting condition

The key to understanding network-based CPGs is the concept of a half-center oscillator. A half-center oscillator consists of two neurons that individually have no rhythm genic ability, but which produce rhythmic outputs when reciprocally coupled. CPG uses sets of differential equations like coupled nonlinear oscillators or neural networks and their solutions, as limit cycles are used to generate the reference signals in the form of travelling waves. The final forms of limit cycles can be modulated online and smoothly and hence allowing the operators of the robots to manipulate the overall locomotion. However, being a still actively researched area, it is still unclear how to design a CPG to obtain a particular locomotion pattern. That is because, most of times, they do not have explicit relations between their parameters and the locomotion parameters

# Chapter 4

# FABRICATION OF SNAKE ROBOT:

After designing next phase was to fabricate whole robot. The whole construction phase was divided in following catagerious

- Fabrication of mechanical parts.
- Installation of electrical components
- Programming the microcontroller

## 4.1. Fabrication of mechanical parts:

After the completion of design and its simulation the next step was to fabricate that design. Aluminum was selected fabricate all mechanical parts as it is light weight and stainless. Each and every part was fabricated in mechanical workshop. After the completion of all parts then they were assembled according to design. The joints were riveted by using rivets. Following are major parts which were fabricated in mechanical workshop.

*Fig: Snake robot bodies (1, 2&3)*

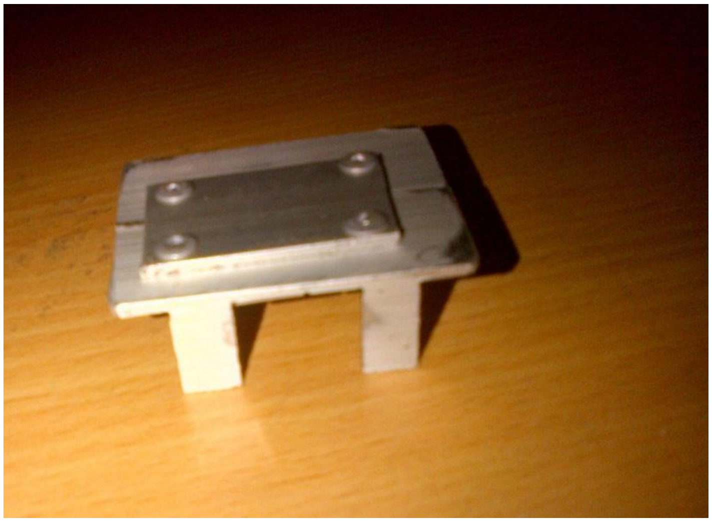
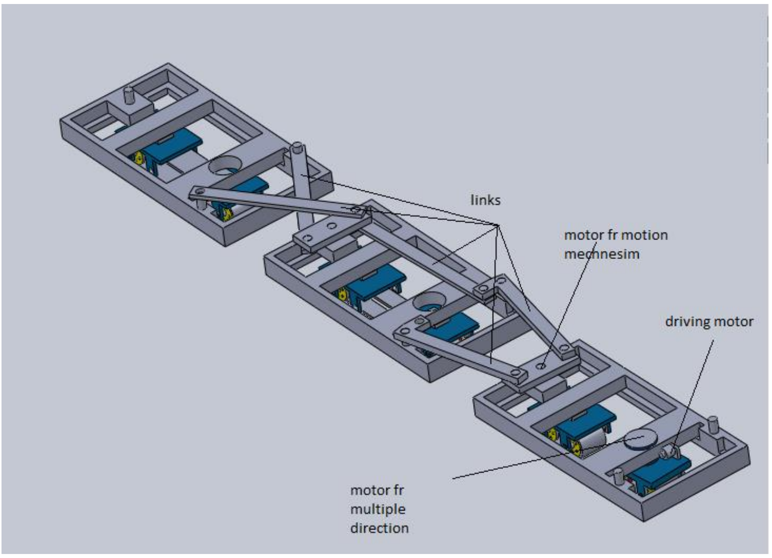


*Fig: roller body.*

## 2.1. Installation of electrical components:

After the completion of whole mechanical structure, all electrical components were installed according to their position. One servo motor was installed in 1st cart another servo motor was installed in second cart and another d.c motor was used to drive the whole snake robot and was installed in rear part of 1st cart.



## *Chapter 5*

# CONCLUSIONS AND FUTURE DEVELOPMENTS

## 5.3. Conclusions:

Snake-inspired locomotion can be used to traverse many different and difficult terrain types, such as small holes, tunnels and gaps, which would prohibit most leg and wheel-based locomotion types. Snake-inspired robots usually have more DOF than is necessary for a given task, thereby providing the robot configuration with a certain degree of redundancy. Numerous snake-inspired robot designs have been developed, however, various robot designs differ greatly in physical configurations and purpose. Snake-inspired robot designs are divided into five categories: (1) robots with passive wheels, (2) robots with active wheels, (3) robots with active treads, (4) robots based on undulation using vertical waves and (5) robots based on undulation using linear expansion. In each of these categories, several robot designs were presented and selected robot designs were discussed in detail observations can be made. it can be assumed from the velocity-length comparison that a faster robot may have a longer length in comparison to another snake-inspired robot. This assumption may be supported by the idea that a longer robot may have additional propulsive force due to additional active joints or modules. Second, at present, snake-inspired robots executing rectilinear-based locomotion are typically slower than robots which use passive and active wheels. Although snake-inspired robot designs have demonstrated general functionality and a number of useful gaits, the current designs still have not been placed into widespread use. Even with better understanding of the current proven designs and their useful features, there are still major design challenges which future designers must resolve to increase the practicability of snake-inspired robots. There are at least four major design challenges which must be addressed to maximize the utility of snake-inspired robots: (1) very small cross-sections, (2) climbing high terrans (3)low velocity and power, and (4) much longer operational.

The proposed design can be modified and more features can be added to this design, this robot currently have no capability to go upstairs are going into water if we made changes into design.

Snake skeletal structure allows wide range of application for environments where classic mechanisms are not effective or fail. Nevertheless, most of works on snake-like robots were only on theoretical level done. Those that were on practical level done are only in the laboratories applicable. Although the research on snake-like robots runs roughly forty years there are still a lot of unresolved issues. The snake-like robots have low power efficiency, high number of degrees of freedom which has to be controlled, low velocity, high manufactured costs because of non-serial production etc. Despite of these issues this field of robotics has good prospects for the future not only in terms of search and rescue operations but in terms of medicine, military and space research as well.

# 5.4. Future work:

1. In future the following improvements can be made
2. Decrease in overall size of robot.
3. Optimization of design through various techniques used in past.
4. Develop motion patterns based on the mathematical model and observations of real snakes that enable a snake robot to detect and exploit obstacles by itself for efficient locomotion. Such a motion pattern will enable a snake robot to move within, for example, a shattered building while looking for people.
5. Construct a smooth exterior of the snake robot. This will enable the snake robot to easily slide beside o rover any irregularities on the ground.
6. Construct robust snake robots with powerful and lightweight joint actuators to be able to continue being operational even though some of the joint actuators break down.

7. Develop a snake robot exterior that can withstand shocks and distortion.
8. Develop control algorithms that consider the global positions of all parts of a snake robot. This will help keep the snake robot from unintentionally colliding with its environment during operations in fragile environments.
9. To detect different obstacle by using image processing technology.
10. To create a mechanism that can collect a sample and can store inside body and bring back for examination.
11. To increase overall working performance of snake robot. So that it can go underwater or can go on higher terrains.

# References:


- Chirikjian and J. Burdick, The kinematics of hyper-redundant robot locomotion, IEEE Trans. Robot. Automat. 11(6), 781–793 (1995).
- Wright, A. Buchan, B. Brown, J. Geist, M. Schwerin, D. Rollinson, M. Tesch and H. Choset, Design and architecture of the unified modular snake robot, IEEE Int. Conf. Robot. Automat.(ICRA 2012), Minneapolis, MN (in press).
- M. Tesch, K. Lipkin, I. Brown, R. L. Hatton, A. Peck, J. Rembisz and H. Choset, Parameterized and scripted gaits for modular snake robots, Adv. Robot., 23, 1131–1158 (2009).
- A. Transeth, Modelling and Control of Snake Robots, Ph.D. dissertation, Norwegian University of Science and Technology (NTNU) (2007).
- Jayne, Kinematics of terrestrial snake locomotion, Copeia, 915–927 (1986).
- J. Gray, The mechanism of locomotion in snakes, J. Exp. Biol. 23(2), 101–123 (1946).
- S. Hirose, Biologically Inspired Robots. Oxford University Press, New York, NY (1993).
- 8. B. Jones and I. Walker, Kinematics for multisection continuum robots, IEEE Trans. Robot., 22(1), 43–55, (2006).
- ZHOU Xusheng. Development of a snake-like robot [J]. ROBOT, 2002, 24(7): 684-687.
- CHEN Li. The implementation of snake robot and its mechanism of locomotion [J]. ROBOT, 2002, 24(7):688-691.
- Roland Bauchot, ed. (1994). Snakes: A Natural History. New York: Sterling Publishing Co., Inc. p. 220. ISBN 1-4027-3181-7.
- ^ Jump up to: a b c d e f g h i j k "Serpentes". Integrated Taxonomic Information System. Retrieved 3 December 2008.
- ^ Jump up to: a b c snake species list at the Reptile Database. Accessed 22 May 2012.

- Jump up ^ Murphy; Henderson, JC; RW (1997). Tales of Giant Snakes: A Historical Natural History of Anacondas and Pythons. Florida, USA: Krieger Pub. Co. p. 221. ISBN 0-89464-995-7.
- ^ Jump up to: a b c d e f g h i j k l m n o p q r Mehrtens, JM (1987). Living Snakes of the World in Color. New York: Sterling Publishers. p. 480. ISBN 0-8069-6460-X.
- Jump up ^ Online Etymology Dictionary, s.v. "snake", retrieved on 22 September 2009.
- Jump up ^ "Definition of serpent". Merriam-Webster Online Dictionary. Retrieved 12 October 2006.
- ^ Jump up to: a b Lee, Michael S. Y.; Andrew F. Hugall, Robin Lawson & John D. Scanlon (2007). "Phylogeny of snakes (Serpentes): combining morphological and molecular data in likelihood, Bayesian and parsimony analyses". Systematics and Biodiversity 5 (4): 371–389. Doi:10.1017/S1477200007002290.
- Jump up ^ Durand, J.F. (2004). "The origin of snakes". Geoscience Africa 2004. Abstract Volume, University of the Witwatersrand, Johannesburg, South Africa, pp. 187.
- Jump up ^ Vidal, N., Rage, J.-C., Couloux, A. and Hedges, S.B. (2009). "Snakes (Serpentes)". Pp. 390-397 in Hedges, S. B. and Kumar, S. (eds.), The Timetree of Life. Oxford University Press.
- Jump up to: a b c d e Sanchez, Alejandro. "Diapsids III: Snakes". Father Sanchez's Web Site of West Indian Natural History. Retrieved 2007-11-26.
- OC Robotics – http://www.ocrobotics.com/ (2012).
- Medrobotics Corporation – http://cardiorobotics.com/ (2012).
- D. I. Goldman and D. L. Hu, The mechanics of slithering locomotion depend on the surroundings, Am. Scientist, 98, 314–323 (2010).
- snake-like robot LI Guoyuan,Department Informatics, Group TAMS
- Augarten, Stan (1983). "The Most Widely Used Computer on a Chip: The TMS 1000". State of the Art: A Photographic History of the Integrated Circuit (New Haven and New York: Ticknor & Fields). ISBN 0-89919-195-9. Retrieved 2009-12-23.

- Jump up to: a b "Oral History Panel on the Development and Promotion of the Intel 8048 Microcontroller". Computer History Museum Oral History, 2008. p. 4. Retrieved 2011-06-28.
- Jump up to: a b c ""Atmel’s Self-Programming Flash Microcontrollers"". 2012-01-24. Retrieved 2008-10-25. by Odd Jostein Svendsli 2003
- D. Reznik and V. Lumelsky, Sensor-based motion planning in three dimensions for a highly redundant robot, Adv. Robot. 9(3), 255–280 (1995).
- 12. S. Yu, S. Ma, B. Li and Y. Wang, An amphibious snake-like robot with terrestrial and aquatic gaits, in: IEEE International Conference on Robotics and Automation, Shanghai, China, pp. 2960–2961 (2011).
- A. Crespi, A. Badertscher, A. Guignard, and A.J. Ijspeert. AmphiBot I: anamphibious snake-like robot. Robotics and Autonomous Systems, 50(4), 163-175, 2005.