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SPIDER BOT LEGS,

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ABSTRACT

since the wheel was invented back in the Stone Age, it was the primary component used in all forms of mechanical transportation. Even today it is the component of choice for almost any type of moving machine like cars. However, the wheel has always had a major disadvantage with short instant elevation changes like stairs. For most uses, climbing stairs or steep jagged rock piles is not a problem which is why the wheel is still almost always used. For the other applications, people looked at animal and human legs which are already proven to work effectively on this type of terrain. The two most effective leg mechanisms are currently Joe Klann's mechanism which resembles a spider leg and Theo Jansen's mechanism which resembles a human leg. We have chosen Theo Jansen's mechanism which has more advantage than Klan's mechanism. The main objective of our paper is to replace the function of wheel with an alternative in order to overcome the difficulty of travelling in uneven terrain. This paper is useful in hazardous material handling, clearing minefields or secures an area without putting anyone at risk, walking in slant positions, walking in mud without struck.

The Jansen linkage is comprised of a eleven-bar mechanism designed by a Dutch artist by the name of Theo Jansen in his renowned collection "Strandbeest." The system reproduces the movement of a leg and is driven. Its scalable design, energy efficiency, and foot show promise of applicability in robotics. Theo Jansen himself has shown the usefulness of this mechanism during his"standbeest" sculptures which use duplicates of their linkage whose cranks have been flipped by end sails to create a walking movement.

It may be utilized as a military robot using a few modifications on it such as Guns, Radar, GPS ,etc . Where military rangers can not go, it may be utilized as a surveillance bot. Even Russian Army has produced some prototypes of the and these robots will be contained in the military soonersince it's an all terrain vehicle it may be utilized for Planetry Exploration such as Mars since it's highest payload to weight ratio compared to some other bot. Additionally it's maximum efficacy for transferring as it's motivated from nature (MOVES LIKE HORSE), it consumes less electricity. It's also very much shock and light absorbing if it's composed of lighter and proper stuff like carbon fiber etc.

We use this mechanism to drive four legged mini robot and actualize this mechanism using the robotic medium.

INTRODUCTION

Transporter vehicles have traditionally used wheel mechanisms like cars and trains. Wheels are ideally suited for movement without vertical fluctuations of the body, and tires with inner rubber tubes absorb shock from a rugged road. On the other hand, biologically-inspired robotics learn mobile flexibility from the morphology of multiple legs and their coordination

Good examples of this are arthropods, like spiders, and the robots are conventionally designed with actuators placed in every joint. In such implementation, robots are good tools to investigate how an animal moves, but they are unable to be a substitute principle for wheels because they don‗t much take into account the maximum load capacity Joint‗s actuators promise mobile flexibility, while the actuator‗s torque performance impacts on the toughness of the robot‗s body. Therefore, in the design of disaster robots, which need to move on rubble and carry rescue devices, continuous tracks or crawlers are popular

Theo Jensen, a Dutch kinetic artist who has attempted to create a bridge between art and engineering by focusing on biological nature, proposed a linkage mechanism to mimic the skeleton of animal legs. This is called ―Theo Jansen mechanism,‖ and provides the animal with a means of moving in a fluid manner. Interestingly, his artificial animals require no electric power for actuators, and do work by weak wind power to drive the gates of multiple legs through a transformation of internal cyclic motion to an elliptical orbit of the legs [4-6]. Even in a version where the body was heavy and five meters in height, the linkage mechanism worked smoothly for walking with minimal power loss. Concepts of the linkage mechanism are in fact found extensively in heavy industrial machines, which are accompanied with hydraulic actuators, such as cranes and shovels. Thus, the linkage has the potential to act as a substitute for wheels, especially in rugged fields. A problem with the Theo Jansen mechanism is the availability and extensibility of walking patterns under bumpy conditions.

The current mechanism concentrates on smoothness at the precise moment the legs touch the ground, and minimizes the force of impact in the toe in order to prevent vertical fluctuations of the body and the breakage parts in the case that the body is heavy. It brings weakness in adaptation to changes of walking fields especially in the presence of obstacles. In order to lift the legs during locomotion, an extension mechanism is crucial for transitions between walking

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and climbing modes. We investigate the possibility of designing a Theo Jansen mechanism involving multiple modes and the generation of a continuous orbit of the legs connecting them. Finally, we propose a solution by using an additional up-and-down motion placed at the joint center [7-9].

This robot has four legs with two degrees of freedom to obtain totally eight degrees of freedom; this is the minimum requirement to be able to form a shape similar to a spider and also to get acceptable movements. This choice obliges to use a controller for eight independent servomotors and it must have some functions to control their positions and speeds. A lot of attention is paid to shapes so that it is possible to avoid challenging solders and bondings which makes it possible to assemble it just using some double stick tape. The chassis of the spider is composed by a base, where servomotors and legs are fixed. In this way the obtained shape is very similar to a spider. Because of the flexibility of the vetronite, an additional part was designed to install under the robot, making it more robust and eliminating dips. It is strongly suggested to make the robot chassis using two coppered sides PCB, in this way all the structure will be stronger. Alternatively, any other lightweight and rigid material like 2mm thick aluminum or 4mm thick plexiglass can be used. It is suggested to paint it in black so that it gets more similar to a spider. The drawings related to the parts of the chassis can be found in the following pages but it is suggested to download them from our website. All the holes represented in the drawings refer to the SERVO209 servomotor model used in this project.

The robot can be assembled following the instructions shown in the drawings and in the pictures of the article. For each leg two servomotors have to be coupled, one is used for rotation movement and the other one is used for lifting and lowering a leg. They can be coupled with double stick tape so that it is possible to easily reuse these servomotors in other projects. Otherwise, it is possible to glue them but a glue optimized for plastic materials has to be used. Complicated software settings for servo motors positioning are not planned so, the maker has to follow the following procedure. First of all, the servomotors have to be taken in the neutral position. It can be done using a servomotor tester or the Spiderin control circuit, because when it turns on, it is programmed to take them to the neutral position. The servomotor arm has to be fixed, through two screws, to the base structure. Robot legs are made by two pieces fixed together by a 3 mm long screw and a nut or alternatively, it is possible to glue them. When the assembly phase is finished, the spider legs must be a little bit higher than the desk surface and the servomotors must be put on the table. The distance between legs must be about 22 cm and each of them has to be orthogonal to the mechanical structure. The The robot can be assembled following the instructions shown in the drawings and in the pictures of the article. For each leg two servomotors have to be coupled, one is used for rotation movement and the other one is used for lifting and lowering a leg. They can be coupled with double stick tape so that it is possible to easily reuse these servomotors in other projects. Otherwise, it is possible to glue them but a glue optimized for plastic materials has to be used. Complicated software settings for servo motors positioning are not planned so, the maker has to follow the following procedure. First of all, the servomotors have to be taken in the neutral position. It can be done using a servomotor tester or the Spiderin control circuit, because when it turns on, it is programmed to take them to the neutral position. The servomotor arm has to be fixed, through two screws, to the base structure. Robot legs are made by two pieces fixed together by a 3 mm long screw and a nut or PCB can be fixed using some spacers and it is possible to use some clamps for wiring. The ultrasonic sensor is installed on the front part of the robot and in this way, it looks like spider eyes.

TECHNOLOGY

Specificatios:

Attractive color

Two assembly choices for you to change the stride length and gait of the spider

The robotic creature designed by yourself

Operating voltage 1.5V Operating Current 180mA

Drive motor 130RPM 11000r/min (per motor)

Hardwere components:

Gears

Legs

DC Motors

Link

Shaft

Coupling

Supporting robot frame

Screw&Bolts

Gears:

Two sets of gears are used for effective transmission. Each set consists of a smaller gear and two bigger gears. Smaller gear consists of 36 teeth and a larger gear consists of 60 teeth, thereby giving a speed reduction ratio of 1.68. The gears are spur gears and are made of nylon plastic gears. Spur gears or straight-cut gears are the simplest type of gear. They consist of a cylinder or disk with the teeth projecting radially, and although they are not straight-sided in form (they are usually of special form to achieve constant drive ratio, mainly involutes, the edge of each tooth is straight and aligned parallel to the axis of rotation. These gears can be meshed together correctly only if they are fitted to parallel shafts. Numerous nonferrous alloys, cast irons, powder-metallurgy and plastics are used in the manufacture of gears. However, steels are most commonly used because of their high strength- to-weight ratio and low cost.

As we create renewable energy from non-renewable energy, like from solar energy and wind energy. Solar energy comes with a condition, like it creates energy only in the presence of sun rays, it requires heat to generate kinetic energy and same with wind energy it requires wind to be blown all the time to generate kinetic energy. This energy can be used in particular places only. Kinetic energy is the energy of motion and can therefore be found in every object that moves. So, in this power generating tiles project we are making use of tiles to generate electricity. Generating off-grid electricity just by walking around or powering streetlights with your footsteps. It consists of spring, gears, two rack and pinion and three generators. The system makes use of rack and pinion arrangement coupled with efficient gearing mechanism to drive mini generators that produce energy when pressed. We make use of harvested kinetic energy generated through vertical press foot movement. These tiles are designed to slightly displace vertically when someone walks on them. This vertical movement results in a rotatory motion that generates electrical energy.

Legs:

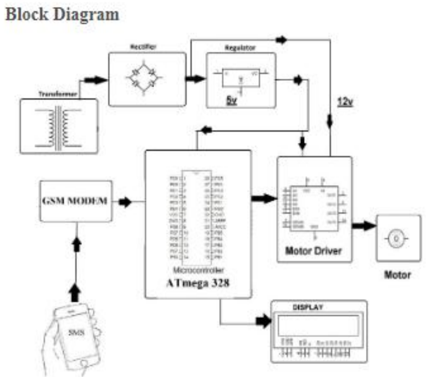
It is outstanding that creatures can go over a rough terrain at speeds which are remarkably higher than practically possible with wheeled vehicles. Indeed, even an individual, by getting down on each of the four legs if necessary, can travel or climb over terrain which is inaccessible for a wheeled or followed vehicle. It is therefore of immense enthusiasm to realize what machines for land locomotion can do if they are intended to imitate nature. Legged robots can be utilized for space missions on extraterrestrial planets and in risky places, for example, within an atomic reactor, giving autonomous legged robots a great potential. Low power consumption and weight are further advantages of walking robots, so it is important to use the minimum number of actuators. In this context, the goal for this project is to fabricate a six legged robot which will stroll using Klann mechanism.

The kinematics of this robot will allow it to move on different terrain at different speeds. It has six links per leg 180 degrees of crank rotation per stride. The linkage consists of the frame, crank, two pivoted rockers, and two couplers all connected by pivot joints. The kinematics of robots structure enables it to convert the rotating motion of the crank into the movement of foot similar to that of creature strolling. The most important benefit of this mechanism is that, it does not require microprocessor, controller and other actuator mechanisms. By copying to the physical structure of legged animals, it may be possible to improve the performance of the mobile robots.

DC MOTORS:

DC motors play an important role in industrial as well as other commercial systems. Motors are a major part of various machinery. So controlling of motors over GSM allows user to control machines from anywhere in the world using SMS message commands. We here use an Atmega microcontroller circuit along with GSM modem, a DC motor, LCD display and required circuitry to make this system. This system first allows user to configure a number from which to receive commands in configuration/settings mode. After that the system listens to SMS messages received on the GSM modem. The on receiving the message it checks of it was received from a registered number. If not, the message is rejected. If the number is valid one system now reads the message to check the command in it. On receiving proper commands the system operated the DC motor to achieve the user desired motion along with speed. The system thus allows to control DC motors over large distances.

BLOCK DIAGRAM



SHAFT:

The behavior of camshaft is obtained by analyzing the collective behavior of the elements to make the camshaft robust at all possible load cases. This analysis is an important step for fixing the optimum size of a camshaft and knowing the dynamic behaviors of the camshaft. Initially, the model is made by the fundamental desires of an engine with the out their background information like the power to be transmitted, forces acting over the camshaft by means that of valve train whereas running at most speed. Here the approach becomes fully CAE based. CAE based approach enriches the Research and limits the time duration. Camshafts are rotating components with critical loads. Hence the determination of actual load values becomes the difficult one compared with alternative rotating members.

This Research provides guidelines to solve such a situation. The objective is to determine the strain distribution on the camshaft for each static and dynamic case and sorting out the issue of safety. We found that the factor of safety is that the ratio of yield durability to the look strength for ductile materials and supreme durability to the look strength. From the FEA output, the maximum design strength is 240.6 N/mm2 from the material property the ultimate tensile strength of the material is 720 N/mm2, then the factor of safety becomes within that safety limit.

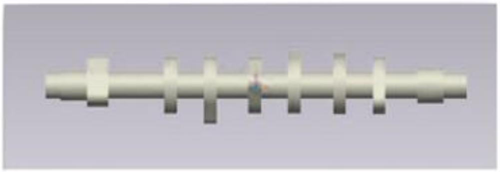


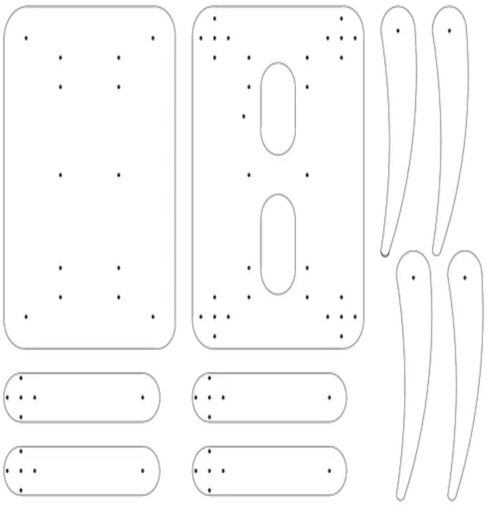
Fig:shaft

Link:

The movement of a body, or link, is studied using geometry so the link is considered to be rigid. The connections between links are modeled as providing ideal movement, pure rotation or sliding for example, and are called joints. A linkage modeled as a network of rigid links and ideal joints is called a kinematic chain. Linkages may be constructed from open chains, closed chains, or a combination of open and closed chains. Each link in a chain is connected by a joint to one or more other links. Thus, a kinematic chain can be modeled as a graph in which the links are paths and the joints are vertices, which is called a linkage graph. The movement of an ideal joint is generally associated with a subgroup of the group of Euclidean displacements. The number of parameters in the subgroup is called the degrees of 34 freedom (DOF) of the joint. Mechanical linkages are usually designed to transform a given input force and movement into a desired output force and movement. The ratio of the output force to the input force is known as the mechanical advantage of the linkage, while the ratio of the input speed to the output speed is known as the speed ratio. The speed ratio and mechanical advantage are defined so they yield the same number in an ideal linkage. 5.7.1. Klann Linkage A kinematic chain, in which one link is fixed or stationary, is called a mechanism, and a linkage designed to be stationary is called a structure The Klann linkage is a planar mechanism designed to simulate the gait of legged animal and function as a wheel replacement. The linkage consists of the frame, a crank, two grounded rockers, and two couplers all connected by pivot joints. The proportions of each of the links in the mechanism are defined to optimize the linearity of the foot for one-half of the rotation of the crank. The remaining rotation of the crank allows the foot to be raised to a predetermined height before returning to the starting position and repeating the cycle. Two of these linkages coupled together at the crank and one-half cycle out of phase with each other will allow the frame of a vehicle to travel parallel to the ground. The Klann linkage provides many of the benefits of more advanced walking vehicles without some of their limitations.

Supporting Robot Frame:

The DFRobot Spider Robot Frame **Kit** is used to make an 4-legged spider-like robot frame which uses a single motor for forward /reverse motion.



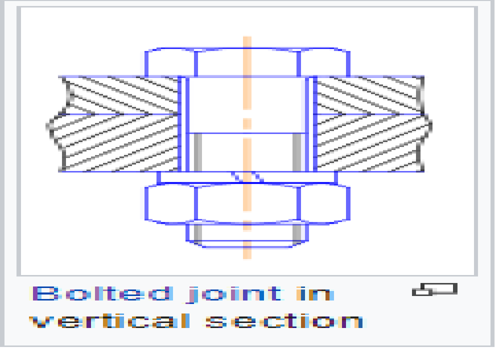
Screws&Bolts:

Screws & Bolts. Socket screws – used with Allen keys to fasten them, therefore are also known as Allen head screws. Machine screws – designed to be used with a tapped hole or interior nut thread. Self tapping screws – have a pointed tapered end that allows them to be drilled into any surface.

A screw is a type of fastener, in some ways similar to a bolt (see *Differentiation between bolt and screw* below), typically made of metal, and characterized by a helical ridge, known as a *male thread* (external thread). Screws are used to fasten materials by digging in and wedging into a material when turned, while the thread cuts grooves in the fastened material that may help pull fastened materials together and prevent pull-out. There are many screws for a variety of materials; those commonly fastened by screws include wood, sheet metal, and plastic.

Bolts are often used to make a bolted joint. This is a combination of the nut applying an axial clamping force and also the shank of the bolt acting as a dowel, pinning the joint against sideways shear forces. For this reason, many bolts have a plain unthreaded shank (called the grip length) as this makes for a better, stronger dowel. The presence of the unthreaded shank has often been given as characteristic of bolts vs. screws,[3] but this is incidental to its use, rather than defining.

The unthreaded grip length should be chosen carefully, to be around the same length as the thickness of the material and washers through which the bolt passes. An overly long unthreaded length prevents the nut from being tightened down correctly. An insufficient unthreaded length results in the threads extending into the hole, and places the dowel shear load onto the threads, which may cause fretting wear on the hole. No more than two turns of the thread should be within the hole.



Bolted joint in vertical section

CONSTRUCTION AND WORKING

Construction It consist of motor or engine mounted at the top. Out of three spur gear one is connected to motor or engine shaft called ‘Driving gear’ and remaining two are meshes with driving gear. The crank is connected to the shaft on which two driven gears are mounted by the shaft. As the motor made to ‘ON’ the driving gear drives. Another two gear, one is clockwise while other is anticlockwise as the gears are rotate in opposite direction. Due to this this rotation resulting in the crank rotation. Crank moves the forcing link gives the momentum in a particular line of action with help of supporting link. The work of supporting link is to move the arm in a particular profile which made by the end point of arm and move back to its normal position i.e. initial position. All these gives the walking motion to the arm like a spider. . 7.2. Working The basic working principle of Klann Mechanism is that when the crank is rotated, a series of relative movements in the various links result in a gait-like movement of the leg. If all the legs in a device are connected to a single motor, the device will be able to move in only one direction (or two directions, if the motor can rotate in both directions). This issue is resolved by using more than one motor. The device can be made to take a turn by using the motors strategically. The operation of the mechanism can be by temporarily installing a wired control box. The box consists of two DPDT switches wired to control the forward and backward motion of the two legs. The legs on each side should be positioned so that either the center leg touches the ground or the front and back leg touch the ground. The leg is the same as an insect's and provides a great deal of stability. To reverse, one set of legs stops (or reverses) while the other set continues. During this time, arrangement of the legs will be lost, but the robot will still be supported by at least three legs. An easy way to align the legs is to loosen the chain sprockets (so you can move the legs independently) and position the middle leg all the way forward and the front and back legs all the way back. Retighten the sprockets, and look out for misalignment of the roller chain and sprockets. If a chain bends to mesh with a sprocket, it is likely to pop off when the robot is in motion. During testing, be on the lookout for things that rub, squeak,and work loose. Keep your wrench handy and adjust gaps and tighten bolts as necessary. Add a dab of oil to those parts that seem to be binding. You may find that a sprocket or gear doesn't stay tightened on a shaft. Look for ways to better secure the component to the shaft, such as by using a set screw or another split lock washer. It may take several hours of "tuning up" to get the robot working at top efficiency. Though the balanced positions achieved by the previous level are adequate when the robot lies on a horizontal surface without disturbing obstacles, in more complex situations they can be non-optimal. The purpose of the adaptation level is to change the targets aimed at by the different balances in order to better the environmental conditions detected. 7.3. Analysis The blue print of the direction of motion for the corresponding directions of rotation of the motors is given in the table. Table.2. Direction of movement of spider Direction of rotation of motor 1 Direction of rotation of motor 2 Forward Clockwise Counter-clockwise Backward Counter-clockwise Clockwise Right Clockwise Clockwise Left Counter-clockwise Counter-clockwise The above functions are executed seamlessly by the Wireless Electronic Remote Control System. Analysis of Mechanical Spider Before doing fabrication work of all parts and assembling, it is necessary to check out deformation and stress in the mechanical spider. Material Assign Aluminum is assign to all linkages and fames and nylon material is assign to gears. Since mechanical spider symmetric on both side of the center plane, considering only half position since result will be same on both side. Also this will reduce the solving time.

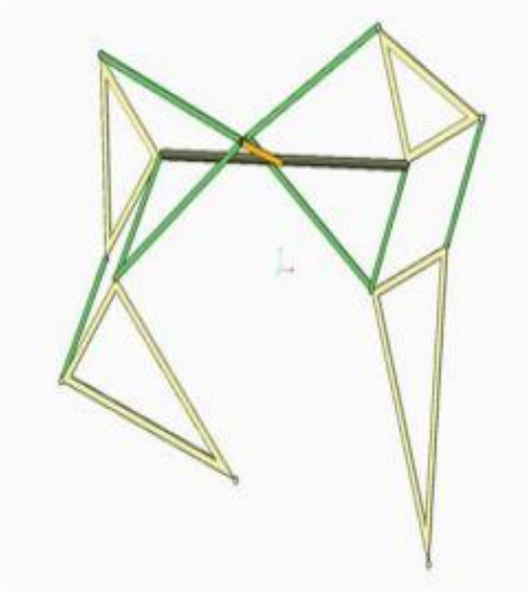


Fig: Soft were designed model

With these references for help I started to develop a design for the system considering dimension in comparison to the tyre analysis report. Initially I came up with a rough line diagram of the design as seen from the right-side view and depicted its motion pattern segregated into three unique diagrams. The following gives a brief description of the motion of the vehicle and its relative placement under the chassis of the truck. The below figures give a brief idea of how the system might work. On considering a practical model of the above line diagram, we intend to replace the front and rear axle along with the tyres with this unique mechanism where in each axle both front and rear will have 4 sister pairs. Thus, we would have 8 pairs in total and overall all 16 legs to support the system. From our survey related to mining and transport we found that a standard truck while loaded has to bear a load up to 16,000 kg. Keeping that in mind I intend to design the system to bear static load of 16,000 kg and accordingly carry out compressive stress analysis across its T joint sections while the body is in static condition. Taking into consideration the analysis report of the tyre I found that the dimensions of a standard tire. The tire model has an outer diameter of 518 mm, 218mm inner diameter and a tyre width of 144 mm. On further calculation, I found the standard dimensions of the mechanism has to scaled 4 times its original and that is how I came up with the standard model which I drew using NXCAD. The following depicts

EVALUATION OF FINAL DESIGN

No more The final designed Theo Jansen device was evaluated through a walking test and its PTC Creo model was also simulated through a computer. The test results indicated that the designed linkage system performed very well in the walking test and successfully met all design requirements. It was proved that the Theo Jansen‘s ratios (‗13 Holy Numbers‘) can be used to determine the link lengths for a linkage system.

By using these numbers, the designer only needs to choose an arbitrary length for one link and all the other link lengths can be easily calculated. Also, the method of construction was proved to be practical, allowing only a small amount of looseness in the link joints. From the assembly test, it was evident that a high precision in fabricating and assembling is critical to guarantee the clearance between crank throw and link so as to avoid binding. In order to eliminate warping, heat-resistant material such as plywood was used to make the base plate and the wood materials were given enough time to cool down before the clamps were released.

PROBLEM ANALYSIS

Assuming all of our calculations are correct and that we are able to obtain all materials specified in this design, we should be in good shape going forward with his project. It is of utmost importance that we do not fall behind schedule. Because of the amount of machining necessary for the completion of this project, we need to be proactive and begin as soon as possible in creation of parts so that we leave plenty of time for assembly, testing, and troubleshooting. Aside from staying on schedule, we will most certainly run into problems of our machined parts not fitting together exactly as we had expected. This will have to be dealt with on a partby-part basis to come up with a workable solution.

The movement of this robots served to us as inspiration for our motion process, which we want to replicate in a biomimetic way. Other approaches are being done by using other mechanism for quadruped walking like parallel mechanism [6], soft materials [7] and so on. Nevertheless, we get a bunch of ideas from other institutes and individual to make our project.

Initially, it’s important to know that the spider has 7 parts by leg (figure 4). These parts are: coxa, trochanter, femur, patella, tibia, metatarsus and tarsus. This spatial arrangement it’s illustrated in the figure 4. From the original anatomy of the spider, we suppress some components which we didn’t need. The reason of this it’s because we wanted to simplify the whole system. Having said this, instead of using the Patella part, we linked the femur and the tibia by a direct joint. The metatarsus and the tibia were united as a single link or part. Similarly, we dismiss the tarsus. All of these dismissals were executed in the robot, but for the kinematics we took account the entirely system for a realistic approach and because we wanted to know what exactly we were suppressing

As its name defines it, our robot is a basic representation of the sipder movements but it will not perform exactly the same body moves since we are using only four legs instead of eight legs.

Named also a Quadrupedrobot since it has four legs and make its movements using these legs, the movment of each leg is related to Legged robots handle terrain better than their wheeled counterparts and move in varied and animalistic ways. However, this makes legged robots more complicated, and less accessible to many makers. and also the making cost and the high depenses that a maker should spend in order to create a full body quadruped since it is based on servo motors or stepper motors and both are more expensive than DC motors that could be used in wheeled robots the other legs in order to identify the roboty body postion and also to control the robot body balance.

A servomotor as defined in wikipedia, is a rotary actuator or linear actuator that allows for precise control of angular or linear position, velocity and acceleration.It consists of a suitable motor coupled to

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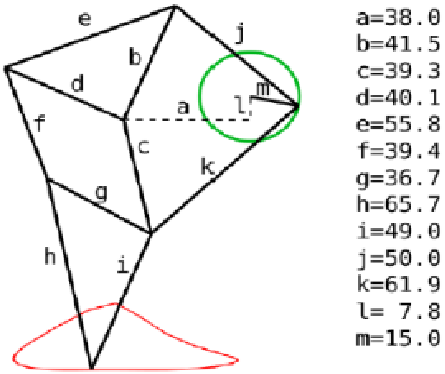
a sensor for position feedback. It also requires a relatively sophisticated controller, often a dedicated module designed specifically for use with servomotors.

Servomotors are not a specific class of motor although the term servomotor is often used to refer to a motor suitable for use in a closed-loop control system.

Generally speaking the control signal is a square wave pulse train. Common frequencies for control signals are 44Hz, 50Hz, and 400Hz. The positive pulse width is what determines the servo position. A positive pulse width of around 0.5ms will cause the servo horn to deflect as much as it can to the left (generally around 45 to 90 degrees depending upon the servo in question). A positive pulse width of around 2.5ms to 3.0ms will cause the servo to deflect to the right as far as it can. A pulse width of around 1.5ms will cause the servo to hold the neutral position at 0 degrees. The output high voltage is generally something between 2.5 volts and 10 volts (with 3V typical). The output low voltage ranges from -40mV to 0V.

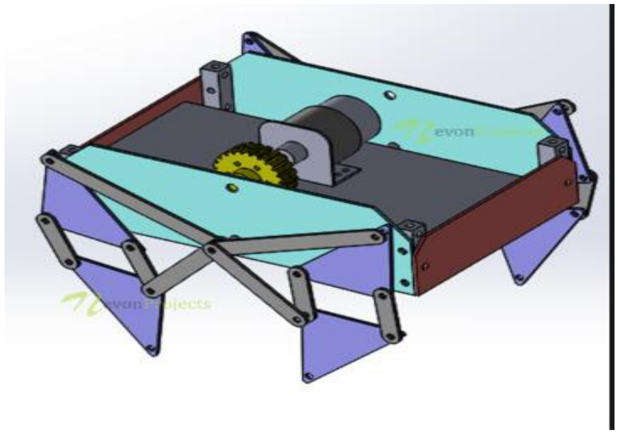
Now let’s review the necessary components that we need for this project, so as I've said, I'm using an Arduino Nano to run all the 12 servo motor of the robot four legs. The project also include an OLED display to display the Cozmo faces and a bluetooth module to control the robot through an android app.

Starting with the first servo, place it in its socket and hold it with its screws, after that turn the servos axe to 180° without placing the screw for the attaches and move to the next part wich is the Femur to connect it to the tibia using the first servo joint axe and the attach piece. The last step to complete the leg is placing the second joint I mean the second servo to hold the third part of the leg which is the Coxa piece.



Now repeat the same thing for all legs to get four legs done ready. After that take the upper chassis and place the rest of servos in them sockets and then connect each leg to the appropriate servo. There is only one last printed part which is the bottom robot chassis in where we will place our circuit board

Now we have the robot almost ready to run but we need to set up the joints angles first, so upload the setup code which allows you to put each servo in the right position by attaching the servos in 90 degrees do not forget to connect the 7V DC battery in order to run the robot.



Leg mechaism:

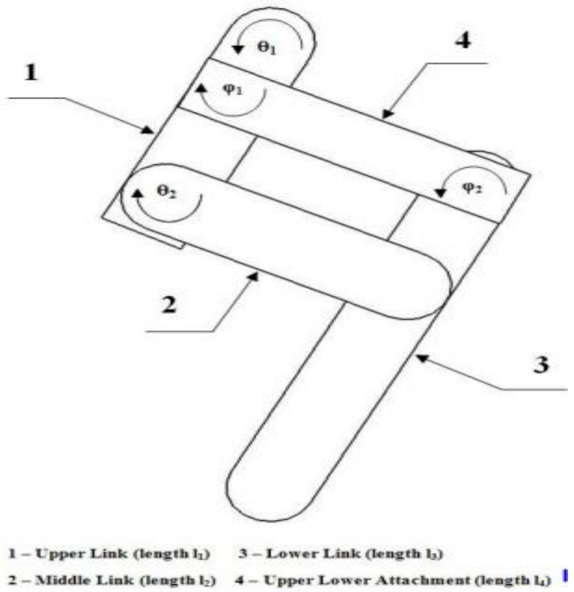
A leg mechanism (walking mechanism) is a mechanical system designed to provide a propulsive force by intermittent frictional contact with the ground. This is in contrast with wheels or continuous tracks which are intended to maintain continuous frictional contact

with the ground. Mechanical legs are linkages that can have one or more actuators, and can perform simple planar or complex motion. Compared to a wheel, a leg mechanism is potentially better fitted to uneven terrain, as it can step over obstacles.

An early design for a leg mechanism called the *Plantigrade Machine* by Pafnuty Chebyshev was shown at the Exposition Universelle (1878). The original engravings for this leg mechanism are available.[2] The design of the leg mechanism for the Ohio State Adaptive Suspension Vehicle (ASV) is presented in the 1988 book *Machines that Walk*.[3] In 1996, W-B. Shieh presented a design methodology for leg mechanisms.

The artwork of Theo Jansen, see Jansen's linkage, has been particularly inspiring for the design of leg mechanisms, as well as the Klann patent, which is the basis for the leg mechanism of the Mondo Spider.

Basic structure of quadruped robot consists mainly of torso frame and legs which are attached to it. Each leg consists of two or more links connected to each other by revolute joints. Also each leg is attached to torso frame by revolute joint. The leg of robot which is actually a mechanism is shown in figure 1 below.



Robot leg mechanisum

As shown in figure 1 above, out of five revolute joints two joints are active joints whose motion is to be controlled. These two joints are Hip flexion/extension (θ1) and Knee flexion/extension (θ2). Each of these joints is controlled by single servomotor. Φ1 and ϕ2 are passive joints and thus are not required to be considered here.

Kinematic modeling Kinematic modeling of quadruped robot is divided into two sections viz. direct kinematics and inverse kinematics. Direct kinematics gives position and orientation of endpoint of robot leg with respect to its base at torso frame given its joint angles . Inverse kinematics gives joint angles given the position and orientation of endpoint of robot leg with respect to its base. 1. Direct kinematics In this paper, a generalized arm matrix for the robot leg is derived using direct kinematics procedure. By substituting joint angle values in the arm matrix for a leg, position and orientation of that leg with respect to torso frame can be found out. Derived generalized arm matrix is

$$T = \begin{bmatrix} \mathrm{Cos}\theta_1 & -\mathrm{Sin}\theta_1 & 0 & (l_3+l_5)*\mathrm{Cos}\theta_1 + l_4*\mathrm{Cos}(\theta_1+\theta_2) \\ \mathrm{Sin}\theta_1 & \mathrm{Cos}\theta_1 & 0 & (l_3+l_5)*\mathrm{Sin}\theta_1 + l_4*\mathrm{Sin}(\theta_1+\theta_2) \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Calculation of joint angles Hip flexion/extension and knee flexion/extension joint angles throughout locomotion are calculated using eq. (2) and (3). Plot of Time (tn) vs. joint angles for legs 1 & 3 and legs 2 & 4 are shown in figures 3 & 4 below respectively

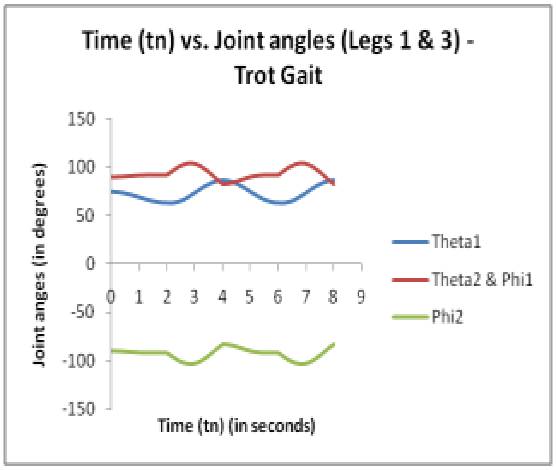


Fig. 3 Plot of Time (tn) vs. Joint angles for legs 1 & 3 in trot gait

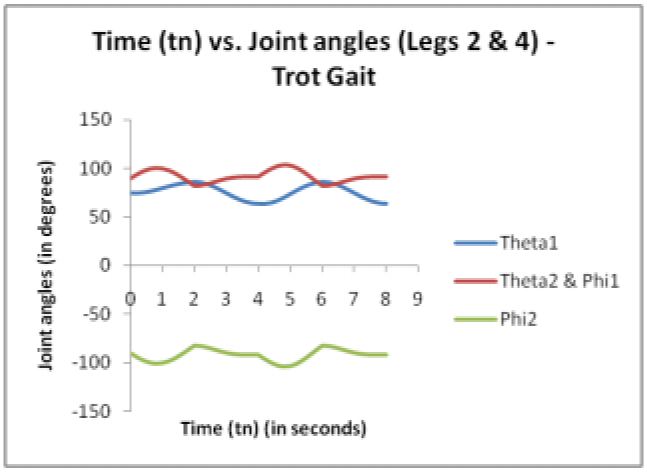


Fig. 4 Plot of Time (tn) vs. Joint angles for legs 2 & 4 in trot gait

Trajectory planning

In robotics, trajectory means the way from one location to another location along which robot moves

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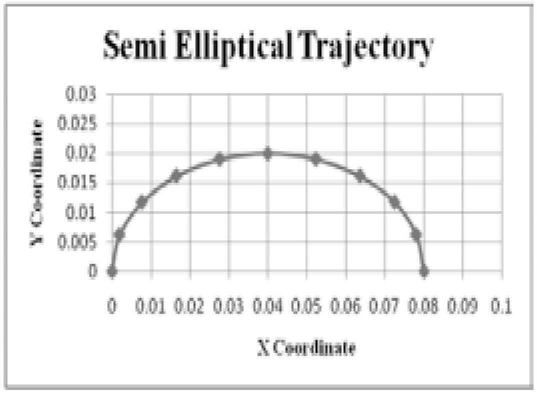
in a controlled manner. In trajectory, along with the path, at what time of interval each part of the path must be attained by the robot is also mentioned. Trajectory planning involves generating a time sequence of the robot leg endpoint position attained by the robot leg. In this paper, robot leg is a planar manipulator thus a 2D curve is the appropriate trajectory. Thus trajectory followed by robot leg endpoint is assumed to be semi-ellipse in 2D plane. In trajectory generation, pairs of front legs and rear legs have been assumed to be 236 mm apart. Torso frame of quadruped robot is maintained at 209 mm from the ground. Semi-elliptical trajectory is shown in figure 2 below.



Contacts When two separate surfaces touch each other such that they become mutually tangent, they are said to be in contact. Contact is changing-status nonlinearity. That is, the stiffness of the system depends on the contact status, whether parts are touching or separated. Since all links are in motion, thus revolute joint is given between contacts of parts. Between gears bonded contact is given. Meshing FEA uses a complex system of points called nodes which make a grid called a mesh. This mesh is programmed to contain the material and structural properties which define how the structure will react to certain loading conditions.

Nodes are assigned at a certain density throughout the material depending on the anticipated stress levels of a particular area. Regions which will receive large amounts of stress usually have a higher node density than those which experience little or no stress. Points of interest may consist of: fracture point of previously tested material, fillets, corners, complex detail, and high stress areas. The mesh acts like a spider web in that from each node, there extends a mesh element to each of the adjacent nodes. This web of vectors is what carries the material properties to the object, creating many elements. Elements: When two nodes get combine the form an element. Nodes are similar to the points in geometry and represent the corner points of an element. The element shape can be changed by moving the nodes in space. Element is an entity into which the system under study is divided. An element shape is specified by nodes. The shape (area, length, and volume) of an element depends on the nodes with which it is made.

Loading and Boundary Conditions Boundary Conditions: the loads and constraints that represent the effect of the surrounding environment on the model. (Everything else that you have not modelled) Types of Boundary Conditions: constraints and loads. Mechanical spider is fixed at four edges. Result of Modal Analysis Modal analysis determine the vibration characteristic i.e. natural frequencies and mode shapes of a structure or a machine component while it is being design. The natural frequencies and mode shapes are important parameters in the design of a structure for dynamic loading conditions. The procedure for a modal analysis consists of four main steps: 1. Build the model. 2. Apply loads and obtain the solution.

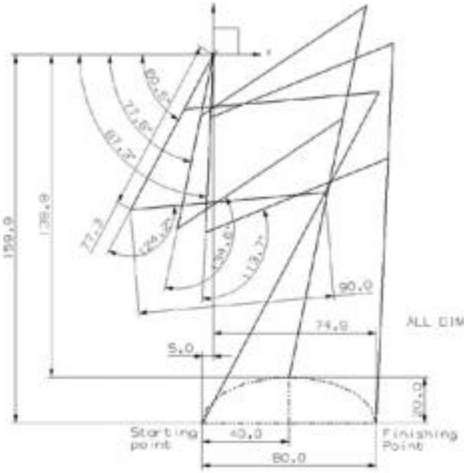


Fig. 5 Line Diagram for Robot Leg

Fabrication of Quadruped Robot

After development of CAD model, dimensions of robot hardware components and overall dimensions of quadruped robot are fixed. Robot hardware components viz. torso frame and legs are fabricated from PVC foam sheet (Sunboard) material. 4 Quadruped Robot Assembly Quadruped robot is assembled from robot hardware components, actuators (servomotors in the given case), control system (controller board and servo shield in the given

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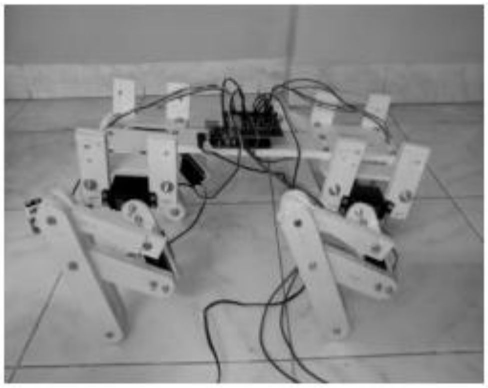
case) and batteries. Assembled quadruped robot is



And at 6 Volts, it has 8.9 kg-cm stall torque. Servomotor with maximum stall torque little higher than requirement is selected due to losses during its operation. Each of this Futaba S3305 servomotor weighs 47 grams. Power sources include 1.5 Volts batteries and 9 Volts batteries. 4 1.5 Volts batteries power servomotors and 9 Volts battery powers Arduino controller board. Regulated DC power supply also required sometimes because of higher current usage of servomotors. Software includes Arduino programming software. Arduino programming software is available on the Arduino website. A program code is developed in arduino programming language for trot and pace gait locomotion separately. It is then fed to controller board for use.

Experimentation

Experiments on locomotion of quadruped robot using trot and pace gaits over flat terrain are performed. The results of experiment are tabulated below. Table 2 below shows joints angles in right hand side legs (when quadruped robot is observed from behind in direction of motion). On comparing the values from experiments and theoretical calculation of inverse kinematics, little difference is found between them. This difference exists because of restriction to servomotor revolution due to its mounting arrangement on quadruped robot. T

Table 2: Results of experiments

X distance (in mm)	Y distance (in mm)	Hip flexion/extension joint angle (in degrees)	Knee flexion/extension joint angle (in degrees)
2	-230	69	73
-33	-218	57	82
-33	-225	59	75
-62.5	-235	55	68

required for it is observed. Mean speed of foot is then calculated as follows. Stride length (λ) = 80 mm Total time taken for one stride = 2.31 seconds Again we have, Stride frequency is the number of strides taken in unit time. Therefore, stride frequency, f =1/2.31

Designing goals

horizontal speed as constant as possible while touching the ground (support phase)

while the foot is not touching the ground, it should move as fast as possible

constant torque/force input (or at least no extreme spikes/changes)

stride height (enough for clearance, not too much to conserve energy)

the foot has to touch the ground for at least half of the cycle for a two/four leg mechanism[or respectively, a third of the cycle for a three/six leg mechanism

minimized moving mass

vertical center of mass always inside the base of support

the speed of each leg or group of legs should be separately controllable for steering

the leg mechanism should allow forward and backward walking

Another design goal can be, that stride height and length etc. can be controlled by the operator. This can relatively easily be achieved with a hydraulic leg mechanism, but is not practicable with a crank-based leg mechanism.

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The optimization has to be done for the whole vehicle – ideally the force/torque variation during a rotation should cancel each other out.

APPLICATIONS

- AGRICULTURE MACHINERY EQUIPMENT

. • RESEARCH AND DEVELOPMENT IN ARMY AND OTHER TECHNOLOGIES.

- IT CAN REPLACE DAILY WAGE WORKERS.

- MINING EXCAVATIONS SYSTEM.

- ROBOTICS.

Advantages:

Another method which I'm favoring is to use tent-peg like idea's. Similar to a tent-peg it greatly increases the grip on the ground allowing it to climb across extreme terrain a tank wouldn't dream off. UNLIKE A TENT-PEG because somehow someone is going to envision a spider-mech with tent-pegs for legs, the legs would use conical shaped ends. The legs compact the earth as they enter the ground, the conical shape quickly increases the surface-area and also sends forces sideways besides downwards to relieve the amount of pressure the ground below needs. The legs could even have a series of cones at the ends extending towards the center of the spider-mech (again with an L shape) to spread out the surface area it stands on even more without losing its grip ability.

The problem is, that if you want to compete with tanks you need to be able to do something a tank can't do, and do it more efficiently and cheaper. Fundamentally, a 4 legged robot is going to need roughly 12 motors as well as a generator and fuel to run it and that is a lot of weight to carry. It can't move as efficiently as a tank over flat ground because it has to lift its legs and body weight, while a tank just rolls around and has to defeat friction, not gravity.

Next if you want more firepower, you need to carry it around with you, so you run into the same problem as before. More weight, means larger motors, which decreases efficiency.

A did a bunch of research into legged robots for my thesis and they aren't going to replace armored vehicles any time soon. The most basic reason, they aren't as efficient in doing what armored or wheeled vehicles are specialized in. They are also very complicated to program, since you have 4/6/8 or more legs which all need to interact versus 2 treads, or some wheels which only really move in 2/4 directions.

Legged mechs advantage is their flexible movements. They won't replace a tank, because a tank can already cover 80-90% of the situations a legged mech would be better in, but a tank would still end up cheaper, more efficient and less prone to breaking (There are a lot more moving parts in a legged mech).

I did a back-of-the-envelope calculation for an 8-legged spider-mech using excavator arms for legs. If the excavator arms are 1/4rth the size of current excavator arms and 1/4rth the strength then you could build a 120 ton spider-mech (and excavator arms probably use the usual 20% safety margin for maximum forces it can take so it can handle even more under stress). If you keep it at around 80 tons it can lose 4 legs and still keep going.

Dis Advantages:

Actually a lot harder than most people expect. Are you really going to fire at a target that constantly accelerates and decelerates and presents a small target? Of course not! You'll fire at where the legs meet the chassis, which puts it in between a tank and a wheeled vehicle in terms of vulnerability. A wheeled vehicle can lose several wheels and still be fairly operational. A tank loses a track and it's a stationary turret/artillery food. A spider-mech would take longer to disable than a tank but have worse consequences for being disabled.

essentially you increase the chance of mechanical problems or failure in direct relation to the number of parts involved.

While tanks are capable of traversing terrain that wheeled vehicles find difficult, when moving on roads the vibration will shake parts loose. To the point that regular vehicles carrying troops will be employed to follow up the tanks to pick up anything falling off the tanks.

WW2 tanks would often be abandoned by their crews not because they were destroyed or damaged but because of mechanical issues.

The other consideration is fragility. If you have a multipedal system it will fail if one of the legs is destroyed, therefor they need protection. One way to do this is to make them smaller to be harder to hit, the

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other way is to add armour, or in other words sacrifice mobility or speed

Defenses

A walker is harder to defend from counter-battery fire and anti-tank fire than a tank. The joints pretty much need to be at least partly exposed, and unless you're using rotary motors in each joint, so does whatever actually moves the legs.

Height is also an issue (though, unlike a tank, a walker could be made to be variable height). Being higher up makes you an easier target (though it can also make it harder for enemies to take cover from you).

On the other side of things, mines may not be as much of an issue for a walker as they are for a tank. If a tank runs over a mine, it's usually either done for, or at least completely stuck there. If a walker steps on a mine, it can just adjust it's stance to compensate for the damaged leg and foot. Of course, this won't work reliably more than once or twice, but it's still enough for the walker to relocate to somewhere better defended for the crew to repair it.

They're more expensive, more complicated and more easily damaged. When you can have a dozen tanks for the cost of one mech, tanks win every battle.

DIMENSTIONS:

Output Result:

Review the results Modes are expanded and deformational on each mode is determined. Deformation at least and highest frequency is within limit and thus body is found to be safe Thus using software Ansys workbench, finite element analysis of mechanical spider of any size can be done in order to check the deformation and stresses in the body.

CONCLUSION

This paper introduces a way to enhance teaching effects in an engineering design course by using the Theo Jansen _Extreme‘ design project. Feedbacks from the students indicated that this project is an educational and rewarding task, in which diverse knowledge and techniques such as engineering design, computer modeling and drawing, kinematic analysis, materials, machining, fabrication, electronics and many other aspects of engineering were applied. In this project, students were able to apply their previous experience in machining and fabrication, use design techniques learned from the Engineering Design course and even refer to the knowledge attained from other resources (Internet, library, etc.) to make logical decisions and attain an optimal prototype along the process. The experiences of teamwork and budget control in the project exposed the students to real-world industrial or research problems.

After finishing this design project, each group explained their design procedure and demonstrated the prototype through oral presentations. They also documented all the design works, analysis results and conclusions in a technical report. The experiences of oral presentation and drafting a technical report developed students‘ oral and written communication skills. As for the actual walker mechanism, much was learned about Theo Jansen devices during the course of this project, including joint quality, required number of linkage sets for stability, weight considerations and driven power availability, etc. With all the knowledge and techniques acquired from the project, the students were confident about designing and fabricating a greatly improved Theo Jansen device within a shorter time. In summary, the project gave students unique experiences in team-based design, build and analysis; thus, all the objectives of the Engineering Design course as required by ABET were satisfyingly met. An assessment from the students also verified the effectiveness of this instructional method. In spite of all its advantages, in the future new elements can be integrated into this project to enhance its efficacy and better simulate a real industrial design environment. For example, the improved design project will give students an opportunity to work with other engineers in small design teams, to develop client relations and to consider more nontechnical constraints (ethical, political, aesthetic, environmental, economic, culture) in their work.

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