

Design of a Bomb Disposing Bot: A Mimic of Tarantula using Klann Linkage

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Abstract

This paper focusses on successful disposal of land mines and bombs that can save millions of valuable lives. The absence of automation in the defense department of our country has led to bloodshed of our soldiers in the past. The unavailability of intelligent war equipment crippled our soldiers in the battle ground. Without knowing the status of the enemy they were fighting blind, as a result those who went for rescuing hostages became hostages. Our robot PATTESH was designed to help the military in situations like this. Pattesh is remote controlled multipurpose octopod (eight legged robot). The motion of a Tarantula is the inspiration behind pattesh. It has mobile base which uses Klann linkage for copying the motion of spider. It can step over curbs, climb stairs, or travel into areas that are currently not accessible with wheels but do not require microprocessor control or multitudes of inefficient actuator mechanisms. It fits into the technological void between these walking devices and axle-driven wheels.

1. Introduction

Pattesh has a manipulator (three degrees of freedom) with a gripper and a wireless camera is also mounted on it. Thus it could be used for reconnaissance; patrolling, handling hazardous materials like bombs, clearing minefields, or secure an area without putting anyone at risk. Besides it also has extra provisions like Leading edge spurs [2, 3, 4] (as found on the legs of a tarantula) on its leg which allows the robot to step onto obstacles taller than its step height, and Spines (as found on the legs of a cockroach) on its foot [4, 5] which allows Pattesh to walk on wire meshes. Thus it is capable of handling rough terrains, especially those found in urban cities. Implementing technologies like these, as soon as possible, could possibly spell the difference between winning and losing a battle.

The absence of automation in the defense department of our country has led to bloodshed of our soldiers in the past. The unavailability of intelligent war equipment crippled our soldiers in the battle ground. Without knowing the status of the enemy they were

fighting blind. Our aim is to provide the military with an intelligent multi- purpose war recruitment that will enhance their standard over the enemies.

Pattesh is a remote controlled multipurpose octopod [1, 4, 6, 7, 10] (eight legged robot). It is capable of stepping over curbs, climb stairs, or travel into areas that are currently not accessible with wheels.

2. Bomb Disposal

Bomb disposal is the process by which hazardous explosive devices are rendered safe. Bomb disposal is an all-encompassing term to describe the separate, but interrelated functions in various fields.

2.1. Military

- Explosive Ordnance Disposal (EOD)
- Improvised Explosive Device Disposal (IEDD)

2.2. Public Safety

- Public Safety Bomb Disposal
- Bomb Squad

2.3. Techniques

Many techniques exist for the making safe of a bomb or munitions. Selection of a technique depends on several variables. The greatest variable is the proximity of the munitions or device to people or critical facilities. Explosives in remote localities are handled very differently from those in densely-populated areas. Contrary to the image portrayed in modern day movies, the role of the Bomb Disposal Operator is to accomplish their task as remotely as possible. Actually laying hands on a bomb is only done in an extremely life-threatening situation, where the hazards to people and critical structures cannot be reduced. Our robot Pattesh is designed to help the army in situations like this.

3. Mobile Base

The mobile base of Pattesh doesn't have any wheels but it has legs. Pattesh has eight legs in total and it moves like a tarantula spider. We have gone for legs instead of wheels for the mobile base because it has many advantages over wheels, when it comes to climbing stairs. We have used Klann linkage to copy the motion of a spider.

3.1. Klann Linkage

The Klann linkage is a six bar linkage named after its inventor. The links are connected by pivot joints and convert the rotating motion of the crank into the movement of a foot similar to that of an animal walking.

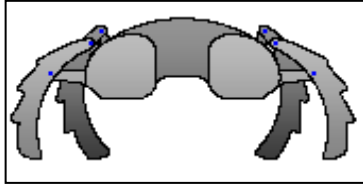


Figure 1. Klann Linkage

Initially it was called the Spider Bike but the applications for this linkage have expanded well beyond the initial design purpose of a human-powered walking machine. This linkage could be utilized almost anywhere a wheel is employed from small wind-up toys to large vehicles capable of transporting people. Two of these legs coupled together at the crank can act as a wheel replacement and provide vehicles with a greater ability to handle obstacles and travel across uneven terrain.

The Klann linkage provides many of the benefits of more advanced walking vehicles without some of their limitations. It can step over curbs, climb stairs, or travel into an area that are currently not accessible with wheels but does not require microprocessor control or multitudes of inefficient actuator mechanisms. It fits into the technological void between these walking devices and axel-driven wheels.

3.1.1. Concept

One hundred and eighty degrees of the input crank results in the straight-line portion of the path traced by the foot. The result of two of these linkages coupled together at the crank and one-half cycle out of phase with each other is a device that can replace a wheel and allow the frame of the vehicle to travel relatively parallel to the ground. The remaining rotation of the input crank allows the foot to be raised to a predetermined height before returning to the starting position and repeating the cycle.

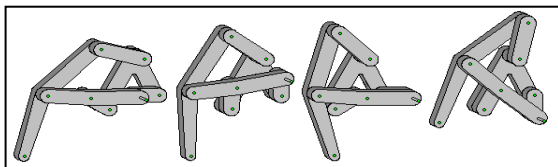


Figure 2. Various Positions of the Linkage

Figure 2 shows a single linkage in the fully extended, mid-stride, retracted, and lifted positions of the

walking cycle. These four figures show the crank (rightmost link in the first figure on the left with the extended pin) in the 0, 90, 180, and 270 degree positions.

The six bar mechanism is designed by using the construction ^{[1][2][3][4]}. The length of the stride was taken to be 20 cm and the mechanism is constructed. Figure 3 shows the construction and dimensional details of the Klann Linkage.

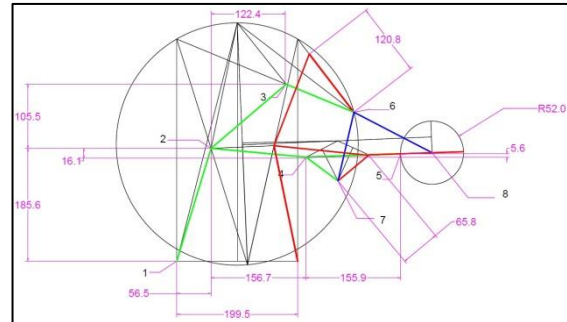


Figure 3. Construction of the Klann Linkage

3.1.2. Motion

A reasonable understanding of the functioning of the linkage can be gained by focusing on a specific point and following it through several cycles. Each of the pivot points is displayed in green. The three positions, grounded to the frame for each leg, are stationary. The upper and lower rockers move back and forth along a fixed arc and the crank traces out a circle.

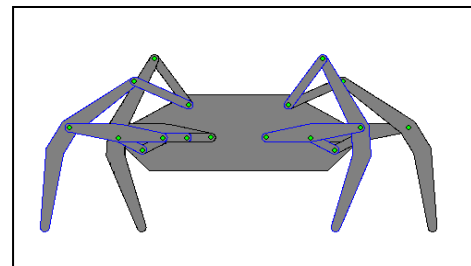


Figure 4. Chassis View of Pattesh

The foot travels along a straight line for one-half rotation of the crank and is raised for the second half. This walking motion provides a smooth ride on a flat surface and it can also be used to paddle through water with appropriately designed legs.

3.2. Actuators

Two 12V DC motors each of torque 2 kg-m and speed 100 rpm, are used to actuate the legs of Pattesh. The legs are mounted on two side panels; each side panel carries four legs (two on the inner side and two on the outer). The two side panels are connected together through five studs of dia 1/4" and

length 10" each. One of the motors drives a pinion gear (10 teeth) which in turn drives two larger gears (50 teeth), these two gears are connected to two cranks on the inner side of the side panel. Thus the power is transmitted likewise:

Motor → Pinion → Gear → Crank.

The two gears act as cranks for the outside legs. We have sacrificed the motor speed for extra torque, as high torque motor available in the market are larger, heavier and consume more power. The gear reduction ratio is 5:1, therefore the actual output torque per motor is 10 kg-m and output speed is 20 rpm.

3.2.1. Differential Drive

The differential drive mechanism implemented in pattesh allows it to turn like a tank. The term 'differential' means that robot turning speed is determined by the speed difference between both sets of legs, each on either side of Pattesh.

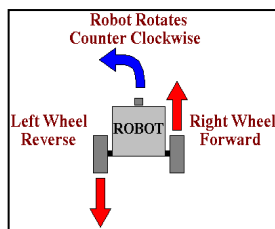


Figure 5. Differential Drive

For example: keep the motor attached to the left side panel still and run the motor attached to the right side panel forward and the robot will turn left, and the opposite is true. But by employing the above drive mechanism 0° turn can be achieved.

4. Manipulator

Pattesh has a remote controlled manipulator with 3 DOF and can lift weights upto 100g. This manipulator allows pattesh to carry the defused bombs and detonate it in safer place.

4.1. Torque Calculations

Torque (T) is defined as a turning or twisting "force" and is calculated using the following relation:

$$T = F * L$$

The force (F) acts at a length (L) from a pivot point. In a vertical plane, the force acting on an object (causing it to fall) is the acceleration due to gravity ($g = 9.81\text{m/s}^2$) multiplied by its mass:

$$F = m * g$$

The force above is also considered the object's weight (W).

$$W = m * g$$

The torque required to hold a mass at a given distance from a pivot is therefore:

$$T = m * g * l$$

This can be found similarly by doing a torque balance about a point. Note that the length L is the perpendicular length from the pivot to the force.

$$\Sigma T = 0 = F * L - T$$

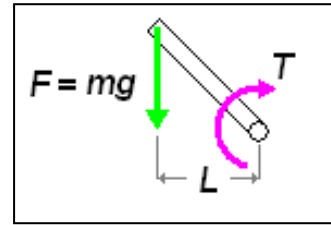


Figure 6. Torque requirement

Therefore, replacing F with $m * g$, we find the same equation above. This method is the more accurate way to find torque (using a torque balance).

$$m * g * l = T_A$$

In order to estimate the torque required at each joint, we must choose the worst case scenario.

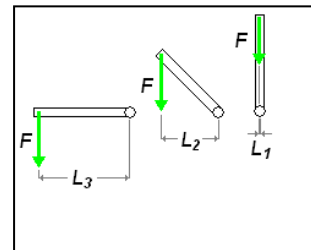


Figure 7. Worst Case Scenario

Figure 7 shows a link of length L which is rotated clockwise. Only the perpendicular component of length between the pivot and the force is taken into account. We observe that this distance decreases from L_3 to L_1 (L_1 being zero). Since the equation for torque is length (or distance) multiplied by the force, the greatest value will be obtained using L_3 , since F does not change. You can similarly rotate the link counterclockwise and observe the same effect.

It can be safe to assume that the actuators in the arm will be subjected to the highest torque when the arm is stretched horizontally. Although your robot may never be designed to encounter this scenario, it should not fail under its own weight if stretched horizontally without a load.

The weight of the object (the "load") being held (A_1 in the diagram), multiplied by the distance between its center of mass and the pivot gives the torque required at the pivot. The tool takes into consideration that the links may have a significant weight (W_1, W_2 etc..) and assumes its center of mass is located at roughly the center of its length. The torques caused by these different masses must be added:

$$T_1 = L_1 * A_1 + \frac{1}{2} L_1 * W_1$$

You may note that the actuator weight A_2 as shown in the diagram below is not included when calculating the torque at that point. This is because the length between its center of mass and the pivot point is zero. Similarly, when calculating the torque required by the actuator A_3 , its own mass is not considered. The torque required at the second joint must be re-calculated with new lengths, as shown below (applied torque shown in pink):

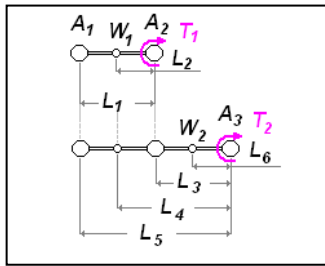


Figure 8. Re-calculated Lengths of the Links

$$T_2 = L_5 * A_1 + L_4 * W_1 + L_3 * A_2 + L_6 * W_2$$

Knowing that the link weight (W_1, W_2) are located in the center (middle) of the lengths, and the distance between actuators (L_1 and L_3 as in the diagram above) we re-write the equation as:

$$T_2 = (L_1 + L_3) * A_1 + (\frac{1}{2} L_1 + L_3) * W_1 + L_3 * A_2 + \frac{1}{2} L_3 * W_2$$

The tool only requires that the user enter the lengths of each link, which would be L_1 and L_3 above so the equation is shown accordingly. The torques at each subsequent joint can be found similarly, by re-calculating the lengths between each weight and each new pivot point.

Note: if any of the joints have two or more motors, they share the torque required evenly. Because the base of the arm is subjected to the highest torque, often two actuators are used instead of one.

4.1.1. More Advanced

The above equations only deal with the case where the robot arm is being held horizontally (not in motion). This is not necessarily the "worst case" scenario. For the arm to move from a rest position, acceleration is required. To solve for this added torque, it is known that the sum of torques acting at a pivot point is equal to the moment of inertia (I) multiplied by the angular acceleration (α):

$$\Sigma T = I * \alpha$$

To calculate the extra torque required to move (i.e. create an angular acceleration) you would calculate the moment of inertia of the part from the end to the pivot using the equation:

$$I = \frac{1}{2} m * r^2$$

Note this equation calculates the moment of inertia about the center of mass. In the case of a robotic arm,

the moment of inertia must take into consideration that the part is being rotated about a pivot point located a distance away from the center of mass and a second term ($+MR^2$) needs to be added. For each joint, the moment of inertia is calculated by adding the products of each individual mass (m_i) by the square of its respective length from the pivot (r_i). Note that the equation for calculating the moment of inertia to consider for actuator N omits the mass of the actuator at the pivot point ($N-1$):

$$I_N = \Sigma \frac{1}{2} m_i * r_i^2 \quad (i = 1 \text{ to } N-1)$$

In all cases considered here, 'r' represents the distance from the center of mass to the pivot. Since the moment of inertia varies tremendously from part to part, angular acceleration is not taken into consideration with the Robot Arm Torque Calculator. Instead, to correct for possible angular acceleration, a "safety factor" is used and set to 2 by default. As with all dynamic tools, inefficiencies in the actuators and joints themselves must also be taken into consideration. This way, the motor at each joint will be able to provide more than the required torque to keep the arm stationary. The required torque to accelerate the weight being support by an actuator from a static position can be calculated using the following relation:

$$\Sigma T = T_N (\text{Holding}) + T_N (\text{Motion})$$

4.2. Actuators and Links

The robotic manipulator consists of three servo motors (two for the links and one for the gripper) of torques 5 kgf-cm (for link 1), 3 kgf-cm (for link 2) and 3kgf-cm (for the gripper).

The length of link 1 is 150 mm and that of link 2 is 120 mm, the gripper length is 120mm. Therefore the total range of the arm is 330 mm (distance from the point on link 1 (where the servo motor is attached) to the center of gravity of the gripper). The free body diagram of the manipulator is given in fig 5.

4.3. Gripper

The gripper has two jaws, one is fixed and the other is movable. The servo motor is mounted on the fixed jaw and the shaft of the servo motor is connected to the movable jaw.

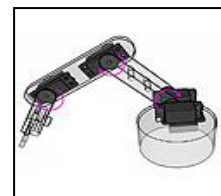


Figure 9. Gripper

The gripper provides half encompassing grip and the frictional torque from it is 3.2kgf-cm.

5. RF Transmitter and Receiver

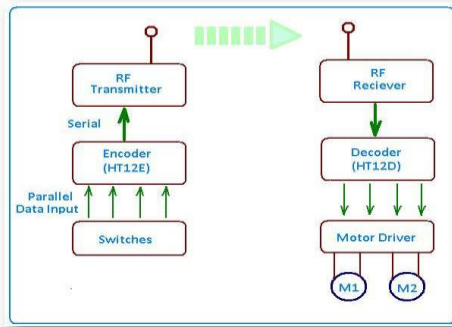


Figure 10. Transmitter Receiver Working

We have used two separate remote controls for the mobile base and manipulator. The transmitter of the mobile base transmits radio waves of 49 MHz and that of the manipulator transmits signals at 29 MHz. The wireless range of pattesh is around 15m. The schematic diagram of the transmitter and receiver is given in fig 9.

6. Wireless Camera

We have used a wireless camera for the purpose of reconnaissance. A mobile phone (Nokia) plays the role of the wireless camera. A software named smartcam allows the mobile phone to transmit the continuous captured picture through Bluetooth to the designated laptop. It has a range of 10m approximately. This software is under development to increase the usability of mobile phone's audio and video options, wireless range of operation and transmission clarity.

7. Additional Applications

Besides bomb disposal Pattesh has many other additional applications like

- Rapid reconnaissance.
- Negotiation with terrorists.
- Helps to locate earth quake and other disaster victims.

8. Photograph of the Bot



Figure 11. Photograph of Pattesh

9. Conclusion

Thus, by implementing the technology in the field of prime importance, which carries the pride and power of the nation through security and safety, PATTESH values the life of our jawans who are absolutely priceless.

10. References

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