MANUAL ROBOT 1

The primary objective of MR1 is to complete its path in the shortest possible time and to achieve 50 points in the first attempt. To achieve the above goals, MR1 is implemented with the following ideas.

1) DRIVE MECHANISM

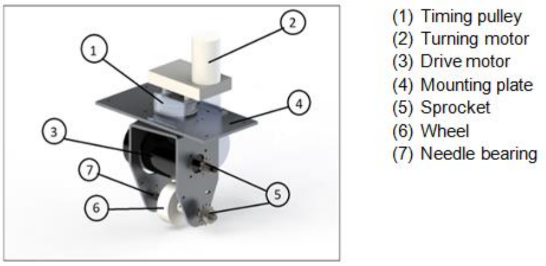


Figure 1: Swerve module

The structure of MR1 consists of a chassis made of aluminium sections. The robot is implemented with a two-wheel swerve drive with an additional four wheels for support. It allows each drive wheel to be powered and turned about its axis giving it unparalleled maneuverability on the field.

The ground clearance of the chassis is kept minimal (14mm) to provide better stability to the robot at high speeds. The driving motors (AmpFlow F24-150-24V) are provided with a gear reduction of 1:1.89 to decrease the load on the motor. Each support wheel consists of a spring-loaded suspension to compensate for the weight distribution of the robot and to provide enough traction. A timing pulley and belt arrangement are used to rotate the swerve module about its axis with only one motor (Sg Mada 500) and an encoder attached to it. This is used to rotate both the driving wheels giving the robot the ability to move in any direction without changing the orientation of the body itself. The drive motors are encoded (incremental encoders: 1024ppr) to ensure precise angular displacement of the module to the required direction. The strategy is to use a sinusoidal wave-like motion to cover the path of the forest in the shortest time. The swerve drive makes it easier to do so. Two ultrasonic sensors (HC SR-04) are used on each side of the robot to provide accurate readings for distance ranges to make the robot semi-autonomous. Gyroscope (MPU 6050) is used to control the yaw of the robot to keep it straight.

Figure 2: Full assembly and drive assembly

2) GEREGE HOLDING AND PASSING MECHANISM

Figure 3: Gerege passing and holding mechanism

In the start of the run, the gerege is held above the upper body of MR1. The MR1 passes the gerege to MR2 using a passive mechanism. For the passing to take place, the gerege is brought down to the required height with the help of a pin removal mechanism. A 300 rpm Johnson motor is used to move the pin out of the way allowing the gerege to fall under its weight while being constrained by a drawer slider. For the passing to take place, the respective parts on MR1 and MR2 must mate. On reaching the fence that demarcates the khangai zone and Gobi urtuu, MR1 will glide against the wall, passing the gerege to MR2. The Shagai is placed such that, the spot where gerege is passed, the Shagai will align itself with the picking mechanism.

3) SHAGAI PICKING AND THROWING MECHANISM

The Shagai is picked from the side which is opposite to the throwing direction. The picking mechanism consists of a gripper with two fingers, one passive and the other actuated by a pneumatic cylinder. The fingers are made of ABS plastic and have a rubber padding for better grip. The actuated finger is a long flat plate to provide an excellent tractive force. The passive finger has a half C like structure for

Figure 4: Picking and throwing mechanism

alignment of the Shagai with the gripper. Once the Shagai is grabbed, the gripper is rotated at an angle of 120°, and the Shagai is then released on the throwing platform. The arm is rotated with the help of a cable drive using pulleys for support. Since the radius of rotation of the arm is more than what is required, an additional passive hinge is provided where the gripper begins to keep the Shagai at the desired position.

The throwing mechanism uses a single pneumatic cylinder of 16mm bore diameter and 400mm stroke length to launch the Shagai from the platform.

To keep the dimensions of the platform inside the dimension of the chassis, the platform is hinged at a point just below the end effector of the piston and is lowered to the desired angle when it is required to throw the Shagai. This needs to be done only once as soon as the forest is clear. The piston is mounted at a height corresponding to the plane parallel to the golden side of the Shagai and passing through its center of mass. To accurately align the Shagai, two rectangular guides (making a ‘V' shape in top view) are attached to the platform. The Shagai is placed coincident to the end effector of the piston to avoid loss of energy due to impact. The stroke length is long enough for the Shagai to gain enough momentum while it is in motion to travel the required distance after it leaves the throwing platform.

By comparing the MATLAB simulation data of the height, angle required and the weight of Shagai with experimental testing, a consistency of 50 points is achieved every time in a single throw.

MANUAL ROBOT 2

MR2 IDEA 1

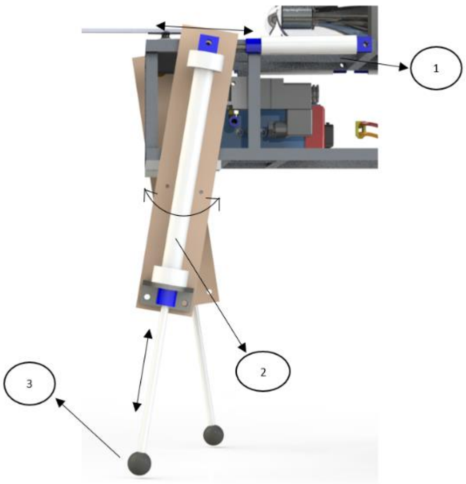
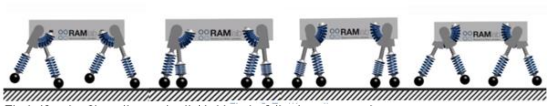


Figure 5: MR2 leg assembly

One of the main factors kept in mind while designing the legged robot is the availability of actuators capable of providing enough specific force/torque for the required gait. For the robot to maintain its dynamic stability at high speeds, the gait selected for locomotion is trotting. Trotting is a form of running adopted by four-legged quadrupeds to minimize energy consumption at that speed and load.

THE STANCE OF THE ROBOT DURING TROTTING GAIT:



The half cycle of bounding can be divided into the following states, as shown:

Stance 1	Alternate legs of the robot meet the ground at a fixed touchdown angle.
Stance 2	The contact point on the ground covers half of the total path of the arc be traversed and gets compressed due to the moment of its weight
Stance 3	In the rest of the arc, the piston is actuated to give the robot the necessary push to hop in the air
Stance 4	This is the flight stance in which the robot is in the air and follows a virtual projectile motion, the next set of alternate legs come in the required position for the touchdown

Figure 6: Trotting gait

Figure 7: MR2 full assembly

The stride length of the robot is approximately 200 mm for one set of diagonal legs. The basic outline of the robot comprises a rectangular chassis and two pneumatic cylinders per leg along with all the necessary components. The chassis is made up of aluminium sections.

Aluminium is preferred because it has an excellent weight to strength/stiffness ratio when compared to other materials such as Acrylic or other Engineering Plastics at the given speed and load. It is optimum for the gait selected.

1) WORKING

A pneumatic cylinder is selected instead of a motor because it is the simplest way to achieve linear actuation and can provide a greater specific force than a motor.

The air inside the cylinder acts as a virtual spring. To obtain a hopping like motion depicted in the trotting gait, a certain momentum needs to be acquired by the component before it leaves contact with the ground. The cylinder after finishing its projectile like trajectory compresses under the weight of the robot when it hits the ground giving the leg a form of passive compliance.

The binary nature of the piston helps in attaining the precise position required. The larger cylinder (bore dia: 18mm, stroke: 140mm) provides the robot with the necessary force to counterbalance the normal reaction as well as the upthrust to lift the body off the ground. The lateral oscillatory motion of the larger piston is provided by, the smaller cylinders (bore dia: 16mm, stroke: 50mm) that help the robot move forward. At any point, a pair of diagonal legs are actuated together to make the robot move. For this motion, the smaller cylinder is hinged on both sides. The rod of the smaller cylinder is connected to the larger cylinder with the help of an eyeball joint. The hinges allow the smaller cylinder to compensate for the rotary movement of the larger piston freely.

The position of the robot in the starting zone is as it is seen in figure 7. For the first half of the arc traced by a leg module, the smaller cylinders and larger cylinders are actuated together. The smaller cylinder is extended in the forward direction whereas the larger cylinder is retracted. Once the larger cylinder becomes perpendicular to the ground, the neutral point is reached. After this point, when the next set of legs come in contact with the ground, the larger cylinders are extended giving the robot enough force to lift off the ground. It is crucial that we match the speed of the piston rod while it is retracted with the speed of the robot falling to the ground when it is in flight.

Once the robot is in flight for the first time, it follows a different set of motion. For the first half of the arc, the cylinders compress due to the weight of the robot and the momentum gained while falling. For the next half of the arc, the larger cylinder is actuated (retracted and extended) to provide the robot with enough force for the upcoming leap. Due to the fixed stroke of the smaller cylinder, the robot has a fixed leg touchdown angle every time.

2) ROBOT TURNING MECHANISM

The idea is to use a dense rotating mass at a distance from the body of the robot. The movement of the mass is brought about with the help of a servo motor (MG995 metal gear servo). Moving this mass to the left or the right half of the sagittal plane would increase the weight of the robot on that side and make the robot turn in the opposite direction. The similar idea is that when the robot loses its contact with the ground, at that instant, this rotating mass is moved to either side of the sagittal plane. The reactive couple acting on the robot at that instant will change the trajectory of the robot to the other direction. The gerege holder is used as the mass to save space. The holder is hinged at a point on a plate that connects the holder and the lifting mechanism. The holder is restricted with the help of a link that connects the holder to the servo motor. As the motor rotates the holder rotates along with it.

Thus, using these mechanisms that help the robot to take a turn when they are in motion, saves time.

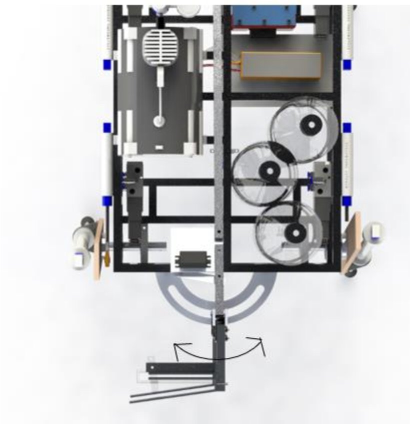


Figure 8: Turning mechanism

3) GEREGE LIFTING MECHANISM

This consist of a passive unactuated gripper that receives the gerege. A lever mechanism is used to raise the gerege to the required height. It is actuated with the help of a pneumatic cylinder. One end of the lever rod is connected to the cylinder and the other end is connected to the gripper. As the cylinder extends the gerege rises up.

Figure 9: Lifting mechanism

MR2 IDEA 2

The stride length per leg of this robot is approximately 250 mm considering the dynamic stability of the robot. The gait selected for this is a two-beat lateral walking gait. This makes the robot easier to turn and stable for locomotion.

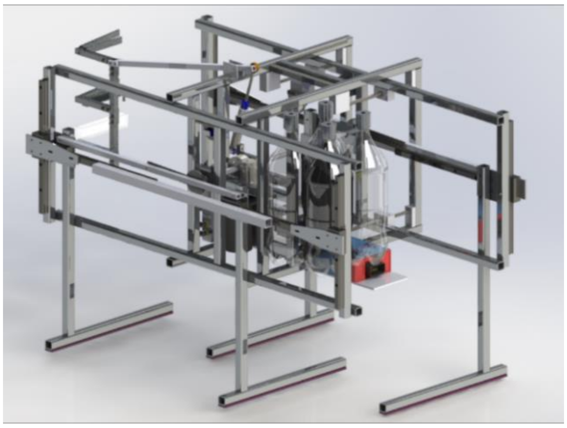


Figure 10: Bot Assembly

1) WORKING

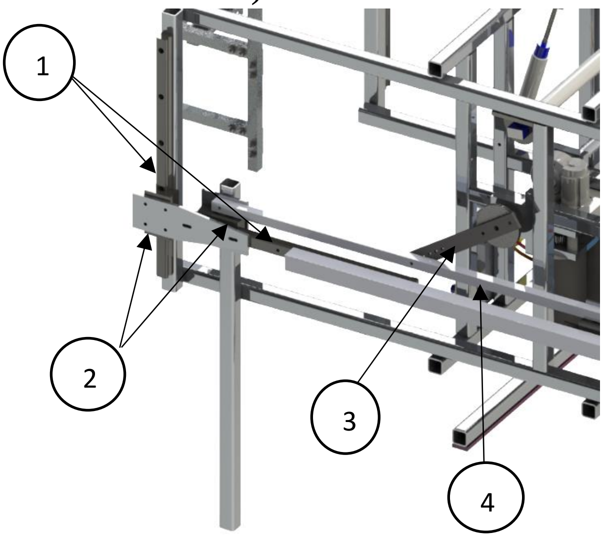


Figure 11: Leg Module.
1: Linear Rail, 2: Carriage, 3: Crank, 4: Connector Link.

The structure of the Quadruped robot consists of a torso frame made by using aluminium sections due to its good weight to stiffness ratio. This mechanism consists of one revolute joint and two prismatic joints. Each leg has 2 DOF. The mechanism consists of a connector link whose both ends are attached to the legs, and legs are constrained to remain always in a vertical position with the help of linear rail and carriage. To mount one set of legs, four linear rails and carriage are used out of which two are in vertical position, and two are in horizontal position. Each leg is connected to the horizontal linear carriage via bolts. Crank is connected to the center the connector link through a revolute joint.

As the crank rotates, the endpoint of the connector link moves in a circular motion of radius of the crank. This motion depicts a rim-less wheel.

Each leg of MR2 is made of "L" shape to increase stability in the static and dynamic condition. The two legs in the same plane are connected by a single link (connector link) to keep them at 500 mm apart and to provide motion. Common crank is attached to the center of that link. This crank is driven by two motors which are connected in a parallel arrangement to drive a single shaft which is connected to the worm gearbox. The purpose of the above arrangement is to increase torque.

At any point, two legs are always in contact with the ground forming CG rectangle and the extended contact ensure that the robot is dynamically stable laterally.

2) TWO BEAT LATERAL WALK

With respect to the sagittal plane, the legs on the lateral side of the robot move together in the same phase. The legs on the other side are 180° out of phase. The common shaft is attached to both the cranks. For the first 180° rotation of the crank, one side of legs are in ground contact, and the robot moves 250 mm forward by one side of legs. For next 180° rotation of the crank, the legs on the other side are in contact with the ground. The robot moves 250mm, thus completing one cycle. Figure 12 shows the walking gait of the robot.

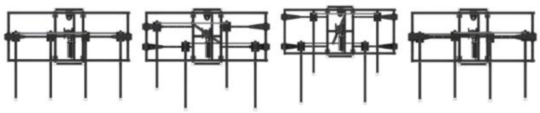


Figure 12: Two beat lateral walking gait.

ROBOT TURNING MECHANISM

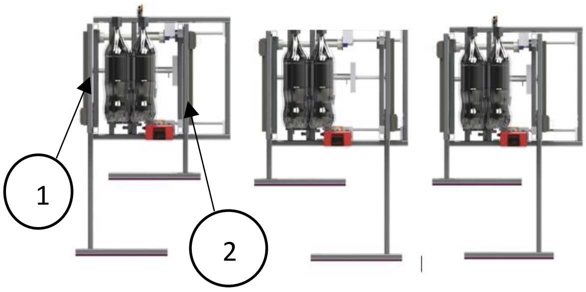


Figure 13: Lateral movement of robot
1: Frame 1, 2: Frame 2

The robot moves in the lateral direction while moving forward or backward while holding a position. The lateral movement is achieved with the help of a pneumatic cylinder. The whole body can be divided into two frames in which one can slide over the other. When the left side of the legs is on the ground contact, the right side of the body will be in the air. At that moment, the piston will actuate (expand), and as a result of this, both the frames will move away from each other. Now the crank rotates next 180 degrees. Now the right side of the legs are in ground contact, and the left side of the body will be in the air. Again, the piston will be actuated (contracts), and as a result of this, both the frames will move towards each other. Hence, the new position of MR2 is 140 mm (stroke length of the cylinder) away from its original position.

3) GEREGE LIFTING MECHANISM

This employs the same mechanism as mentioned in the first idea.

Figure 14: Lifting mechanism

MATLAB SIMULATION AND TESTING FOR MR1

The purpose of this graph is to find out the approximate angle at which we can throw the Shagai to score 50 points. With the help of our Simscape model of Shagai projection, we were able to determine the appropriate angle to launch the Shagai at. The x-axis denotes the angle at which the Shagai is thrown and the y-axis denotes the result attained after falling in the landing zone.

The graph has 5 different lines where each line corresponds to a Shagai of different weight.

It is observed that if the Shagai is thrown in the angle range of 11.4° to 13.2° (w.r.t ground), the Shagai will land to score 50 points irrespective of the weight.