Design Details Document

ABSTRACT- The theme of ABU Robocon "GREAT URTUU- message relaying system" requires two messengers to work in coordination for effective transfer of a message. To comply with the problem statement, the MR1 robot has distinct features like a holonomic drive along with various subsystems. The subsystems include a Gerege holding and passing mechanism, an intercepting mechanism for picking Shagai and a lever-based throwing mechanism. The MR2 design requirements are that of a robotic replication of a horse i.e. a 4-legged robot, carrying the message through various obstacles. MR2 is responsible for completing the final task and convey the message of victory to the world by raising the Gerege. Our effort in fulfilling the problem statement for MR2 has resulted in the development of modified Klann mechanism and the scissor mechanism for conveying victory.

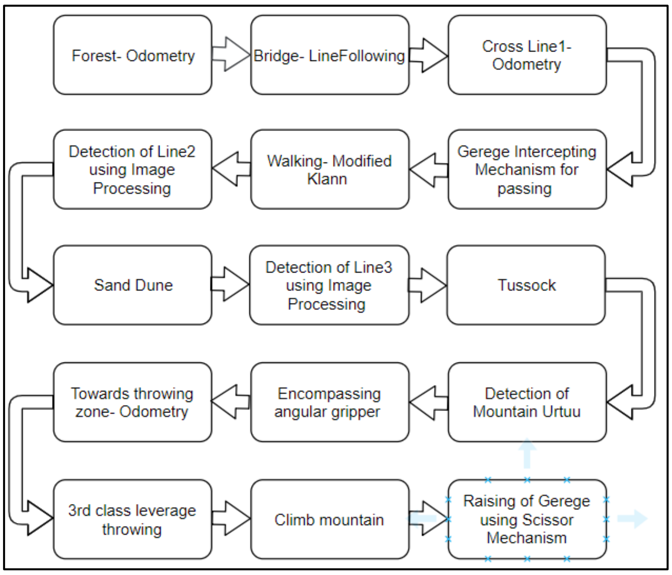


Fig 1.1- Game Plan

I. Messenger Robot-1

A. Dimensional and weight consideration:

- The robot needs to be robust and accessible so that changes can be made conveniently if the need arises.
- Stability of robot is of prime importance hence the centre of gravity should be as close to the ground so that toppling of the robot is avoided.
- It should be able to sustain its own weight along with all the mounted mechanisms in all static and dynamic conditions.

B. Drive of MR1

A four-wheeled omnidirectional drive is used for MR1 as it provides instantaneous motion in any direction. The chassis is made up of aluminum extruded strut consisting of 152 mm diameter Omni wheels whose shaft is supported by the pedestal bearing. The shaft of the wheel is coupled to the motor shaft through spider-jaw coupling which provides shock absorption and torsional stiffness.

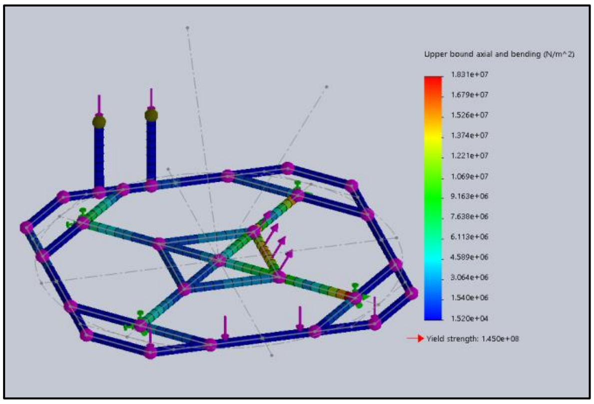


Fig 1.2- Stress Analysis of Chassis

Planetary geared DC motor for drive

Rated Current	1900 mA
Rated Torque	7.63 kg-cm
Rated Voltage	24 V
Rated Speed	468 rpm

C. Driving the MR1

The driving of MR1 is categorized into:

Odometry: To trace any desired path using data from motion sensors, in reference to the starting point.

Mapping of coordinates system: Two Optical Rotary Encoders are used for calculating the displacement of the robot in X & Y direction with respect to the start position. Both the encoders are hinged at bottom of chassis and are perpendicular to each other. 58mm diameter Omni wheels are coupled to the encoders.

Navigating to the desired position: The robot moves with some velocity towards the planned trajectory i.e. the angle(ϕ) between the initial coordinate and desired coordinate. While traversing, if any deviation is found in the path a new angle(θ) is followed and computed using the current position and the desired position. When distance to be covered is less than some tolerance(small) value, the robot stops.

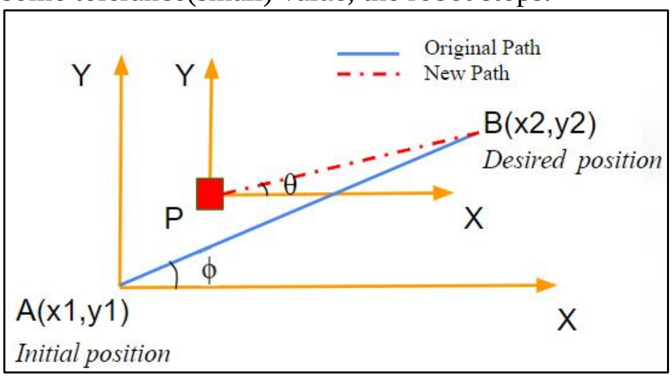


Fig 1.3- Navigation to a point

A feedback from the IMU sensor (accelerometer, gyroscope and compass) is continuously used for maintaining the orientation of the robot.
The robot can always reach to any desired position using this method. It makes the robot independent of skidding of wheels(152mm) but it won't trace a perfect straight line as skidding of wheels may deviate it from its path.
Note- <u>Velocity as a function of distance is used.</u>
Line Following: Follow the route indicated by white-guidelines using two Line sensor arrays (LSA08). The following algorithms are carried out simultaneously in keeping the robot on the line with a constant orientation.
<u>Line Control</u>**:** It determines the direction of the velocity of the robot with constant orientation, using the feedback of any one of sensor. (depending upon direction of motion)
<u>Omega Control</u>**:** It corrects the orientation of the robot using the difference of feedbacks from the two sensors.
Manual Control: Controlling of direction, speed, and orientation of the robot using a remote controller. Bluetooth Modules are used for communication between the remote controller and the robot (micro controller).
**Manual Controller can be used in case of undesirable response by odometry or line following.*

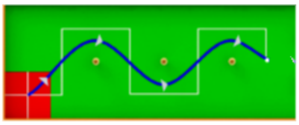
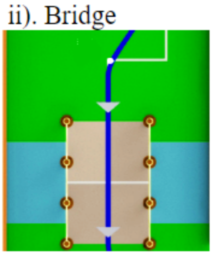
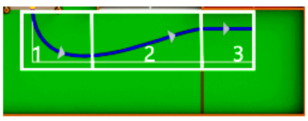
<u>Path</u>	**<u>Method</u>**
i). Khangai Urtuu and Forest 	**Odometry** A sine wave route will be traced so that covered distance is minimum and the change in direction of velocity of the robot is smooth.
ii). Bridge 	**Line Following** Any deviation in the path in the case of Odometry will result in change of direction of travel. This increases the probability of the robot to collide at the bridge. Line Following is reliable as the robot will follow the direction of white line.
iii). Cross Line 1 	**Odometry** The path is divided into an arc and two straight lines.

Table 1.0

D. Loading of Shagai

Design Considerations:

- Precise control is required to pick the Shagai without damaging it.
- A Lightweight mechanism is needed to reduce torque requirements of the actuator.
- Tolerance for gripping is required in case of poor alignment of Shagai in the gripper.

Hence, 2 jaw encompassing angular gripper is used for gripping the Shagai. Angular type of gripper is implemented because it provides better gripping for irregular shapes as compared to parallel type. Encompassing type of gripper is used because it increases the gripping area resulting in decrease of pressure applied on the Shagai.
The 2 jaws are actuated using a pneumatic linear actuator. The stroke length required to actuate the gripper is calculated on the basis of angular distance needed to be covered by the jaws to grip the Shagai. Bore diameter is calculated on the basis of gripping force required to hold the Shagai. The angular motion of gripper mechanism for loading Shagai is controlled by high torque motor.

Fig 1.4- Encompassing Angular Gripper

The movement of the gripper is constrained by the two limit switches. The following flow is implemented when the Shagai needs to be gripped:

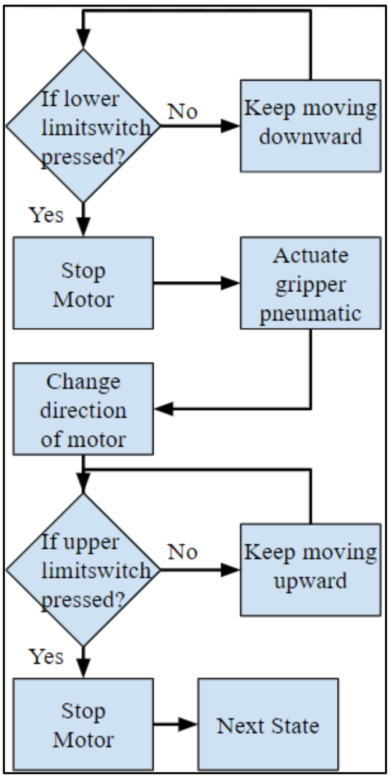


Fig 1.4 Flow Diagram of Gripping

Once the Shagai is gripped and lifted, the MR1 moves to the throwing zone using Odometry & simultaneously an IR proximity is used to sense the Shagai so that the robot can get the feedback if the Shagai accidently falls down and new Shagai needs to be gripped.

DC geared Mech-Tex motor for movement of gripper

Rated Current	3000 mA
Rated Torque	24 kg-cm
Rated Voltage	12 V
Rated Speed	60 rpm

Pneumatic linear actuator for actuation of jaws

Bore Diameter	12mm
Stroke length	50mm

E. Throwing of Shagai

Design Considerations:

- The mechanism should be capable of making a successful throw from any point in the throwing zone.
- Ability to throw the Shagai with minimum air consumption, resulting in maximum number of throws.

It is based on class three lever system. Here the load is Shagai, Fulcrum is the pivot, Effort is the force applied by pneumatic linear actuator. A Quick Exhaust Valve is used to increase the velocity in forward stroke of pneumatic liner actuator which causes increment of momentum of Shagai.

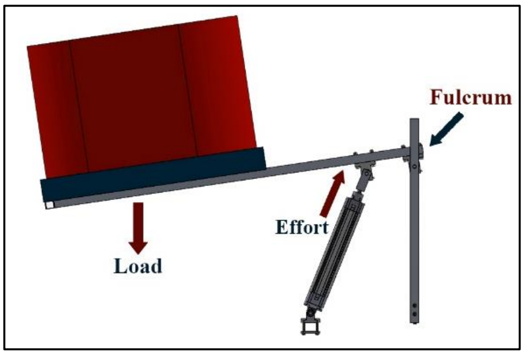


Fig 1.5- Throwing Mechanism

Pneumatic linear actuator for throwing

Bore Diameter	32mm
Stroke length	150mm

Once the Shagai is gripped and lifted, the MR1 will move towards a predefined position in the throwing zone using Odometry. A control signal from manual controller is awaited to actuate the gripper pneumatic to release the Shagai on loading platform and throw it. Before throwing, the weight of the loaded Shagai is calculated using the load sensor and accordingly the pressure is regulated. Thus, the point of variable weight of Shagai as mentioned in the updated rulebook is considered.

F. Gerege holding and passing

Design Considerations:

- The Gerege needs to be held vertical.
- More than 70 percent of Gerege should be visible.
- The mechanism should be compatible enough to adapt both blue and red side of arena.
- It should require least alignment and precision for passing the Gerege.
- It should be able to maintain the face of the Gerege in the direction of motion

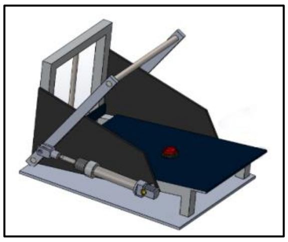


Fig 1.6- Interceptor Box

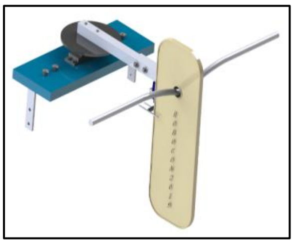


Fig 1.7 Gerege Holding Cane

Specially designed structure called the interceptor placed on MR2.

The Gerege is held vertical using a specially designed cane through the Gerege hole. When MR1 is moving towards MR2 for Gerege passing, the Gerege held on MR1 will be obstructed by the interceptor box placed on MR2 resulting in Gerege sliding out from the cane into the interceptor box. According to the revised FAQs, the face of the Gerege should always be towards the direction of motion. For fulfilling that change servo motor is employed.

To avoid the tilting of the Gerege another servo motor with arm is employed.

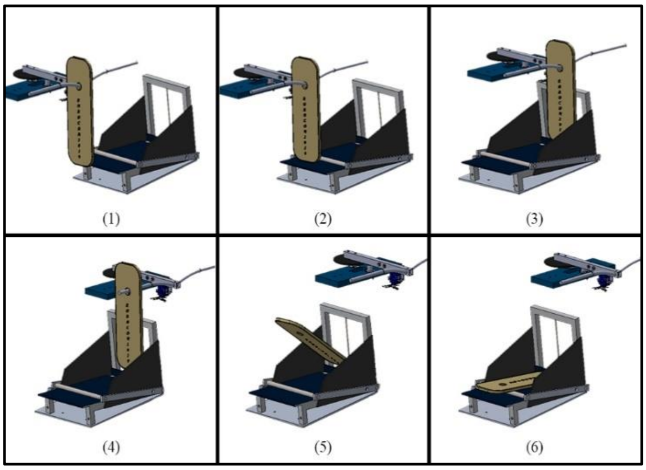


Fig 1.8 Gerege Passing Sequence

II. Messenger Robot-2

A. Walking mechanism design requirements

- Minimum displacement of legs perpendicular to the ground must be 15 cm in order to smoothly overcome all the obstacles.
- Legs must have enough grip in order to climb the mountain without slipping.
- The speed of sets of legs should be separately controllable for rotating.

Gait considerations-

- The base of the gait pattern needs to be flat in order to avoid a high reaction force which could result in poor stability.
- The symmetric pattern is essential to prevent any deviation (by small angles) during walking.
- The peak point in the gait pattern needs to be smooth in order to decrease jerks on the robot.

The Klann mechanism is modified according to the above requirements and a desired gait pattern is achieved.

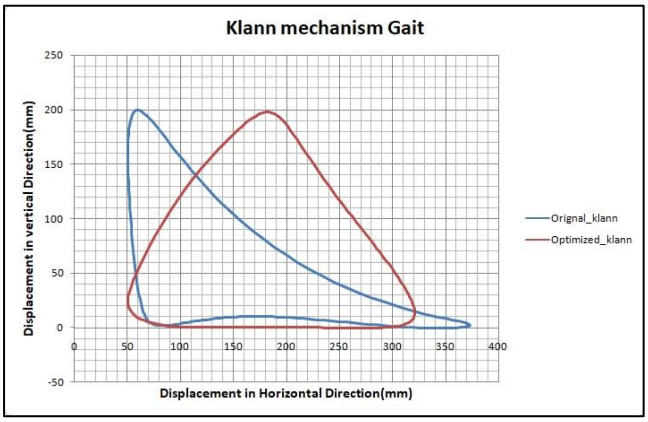


Fig 2.0- Gait Comparison

While crossing the Tussock, the rope may get entangled in the robot's leg, in order to avoid this a special type of shoe accessory has been designed. The shape of this accessory is responsible for making the rope slide over the leg.

Since the gait pattern is designed according to **trot** movement of legs, following requirements need to be fulfilled.

- Legs on the same side need to have a phase difference of 180 degree.
- Diagonally opposite legs need to have identical phase.

The Gerege has been received from MR1 is detected using IR proximity sensor.

B. Driving

Walking: The robot mechanics work on phase maintenance between right and left sets of legs while moving with some base speed. The phase maintenance is defined as keeping angular difference between right and left set of legs to be zero. A control algorithm is used to maintain the phase. To estimate the angle of each set of legs, Rotary Encoders are used.

Rotate: The robot rotates when both of the sets of leg's motions are in opposite direction along with the same rate of angular shift. Hence the sets of legs follow a symmetric pattern. While rotating, the yaw of the robot can be assured using the feedbacks of IMU (accelerometer, gyroscope and magnetometer) and the Encoders fused together.

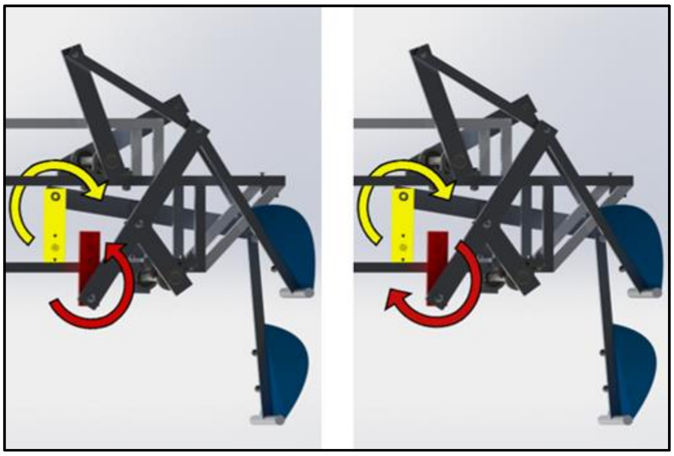


Fig 2.1- Rotate Fig 2.2- Walking

Align: The robot will achieve initial mechanical phase, from any position.

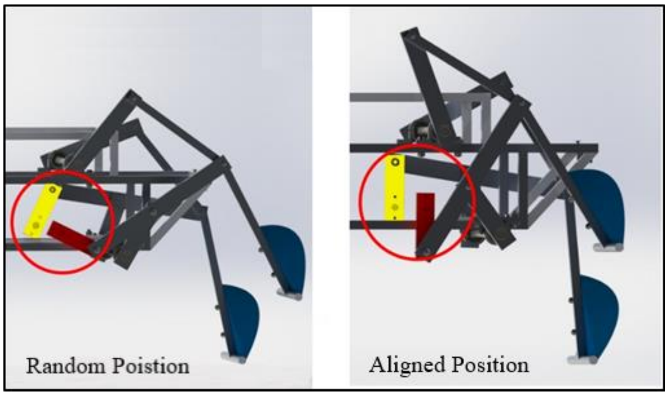


Fig 2.3 Position of cranks from random position to aligned position

Note: We need to align the robot, whenever we switch from one state to another.

Planetary geared DC motor for drive

Rated Current	3500 mA
Rated Torque	18 kg-cm
Rated Voltage	24 V
Rated Speed	148 rpm

C. Detection of Red/Blue Line

A 720p Logitech camera is used for Image processing on raspberry pi (model 3B+). Images that we get from the camera has several kinds of noise in them and take up a large part of processing. To remove this noise, we perform the following actions on images:

- Converting RGB to GREY
- Applying threshold
- Applying Gaussian blur
- Applying the HSV model
- Applying a morphological operator (dilate & erode)

After all these processes we take the image and apply "AND" operation with the desired colour to detect and find its contour. If the contour is greater than a certain limit, it is considered as a line of desired colour.

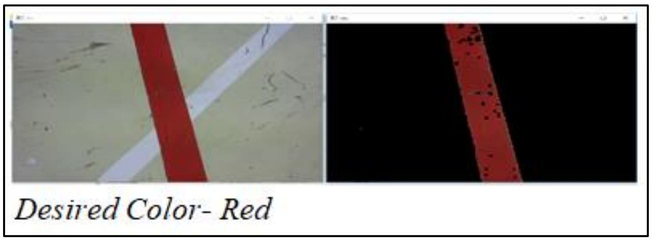


Fig 2.4- Detection of Red Colour

D. Obstacles:

The indication that the obstacle is being approached has been done by the following:

Sand Dune: Once the Line2 is detected by camera1, the robot will enter the align state wherein the initial mechanical phase will be achieved. After aligning, the robot will rotate 45 degrees from the original orientation, align again and move forward.

Tussock: Once the Line3 is detected by camera1, the robot will enter the align state, achieve 90 degrees rotation from original orientation, align again and move forward. Now, when camera2 detects Line 3 robot moves one cycle forward, aligns, rotates to an orientation 180 degrees from initial, align again and move forward. After crossing the Tussock, camera 1 and 2 wait for red/blue colour to appear. As soon as robot reaches Mountain Urtuu, both cameras detect red/blue colour and this indicates robot to suspend motion.

Mountain: As soon as MR1 scores 50 points by throwing Shagai, an operator signals MR2 to begin mountain climbing through an IR proximity sensor. When robot reaches the Uukhai zone, both the cameras will detect red/blue colour, which indicates robot to lift the Gerege.

Note: An indication to climb mountain is given by the operator through IR proximity that 50+ points have been scored by MR1.

E. Gerege holding and raising

Gerege is to be held vertical relative to ground when MR2 reaches to Uukhai zone. To achieve this a pneumatic stand will be used for picking up the Gerege in the interceptor box to its desired position.

A scissor mechanism is used to regulate the height of the interceptor box holding the Gerege. To estimate the height an ultrasonic sensor is used, thus providing the added advantage of variable height to the robot and satisfying the need of dimension requirements at different stages of the arena.The orientation of the interceptor box would be set according to red/blue side of the arena.

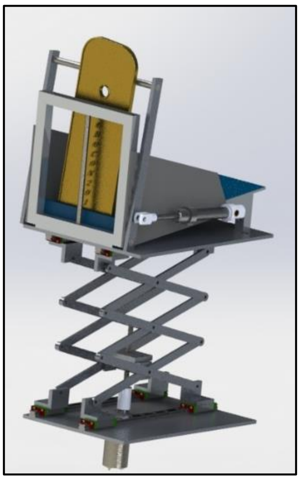


Fig 2.5 Scissor Mechanism

Johnson geared DC motor for scissor lifting

Rated Current	900 mA
Rated Torque	0.8kg-cm
Rated Voltage	12 V
Rated Speed	1000 rpm

Pneumatic linear actuator for Gerege holding(vertical)

Bore Diameter	12 mm
Stroke length	50 mm

REFERENCES

[1] Guidelines for the design of *robotic gripping systems*- Jernej Prešeren, Dejan Avguštin, Tadej Mravlje.

[2] Design and Fabrication of Spider by Using *Klann's Mechanism* for Remote Sensing- Nagarajan Ramalingam.

[3] *Velocity and Acceleration Cones for Kinematic and Dynamic Constraints* on Omni-Directional Mobile Robots- Jianhua Wu, Robert L. Williams II.

[4] Design and Implementation of *an AHRS Based on MEMS Sensors and Complementary Filtering*- Yangzhu Wang, Ning Li, Xi Chen, Miao Liu.

[5] *Self-Localization and Navigation of Holonomic Mobile Robot* using Omni-Directional Wheel Odometry- Jiraphan Inthiam and Chirdpong Deelertpaiboon

[6] *Image Processing*- www.opencv.org

[7] *PID*- https://en.wikipedia.org/wiki/PID_controller