Mechatronics
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Lecture - 38
ABU Robocon 2019 – Part 1

I welcome you all to this NPTEL online certification course on Mechatronics. Today, I am going to talk about again the design of the mechatronic system, and this example which I have taken is from the Robocon 2019. So, ABU is Asia Broadcasting Union Robocon 209 is a student competition where they are given a problem statement and based on that problem statement, and they have to prepare the robots and compete.

So, these types of competitions are very good learning opportunities for the students and to implement whatever mechatronic system design, modeling, testing, execution, and all these concepts in a real-world problem.

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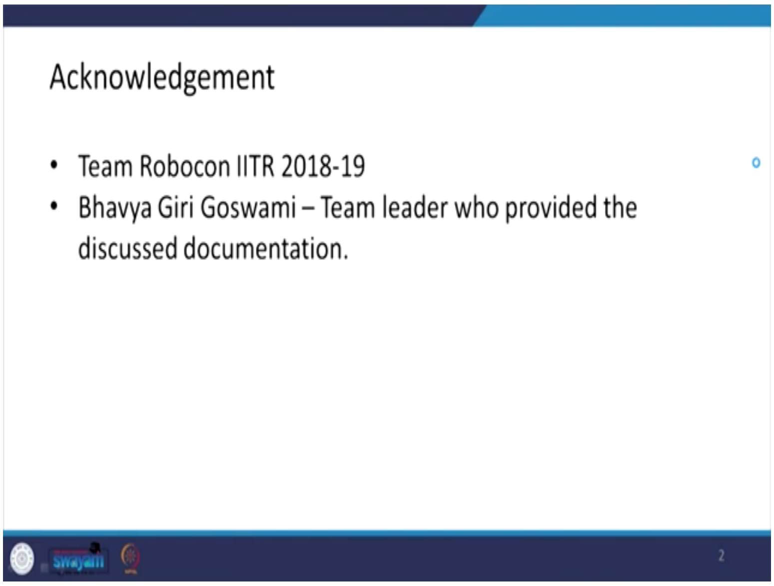

Let me begin with the acknowledgment. I would like to thank Robocon, IIT Roorkee, 2018-19 team for this. Bhavya Giri Goswami, the team leader of this team Robocon, IIT Roorkee, 2018-19 team, provided the discussed document over here. I have been associated with this competition as a mentor, initially for several years since 2008 for the IIT Roorkee team. And later since last 5-6 years as the national judge for this particular competition.

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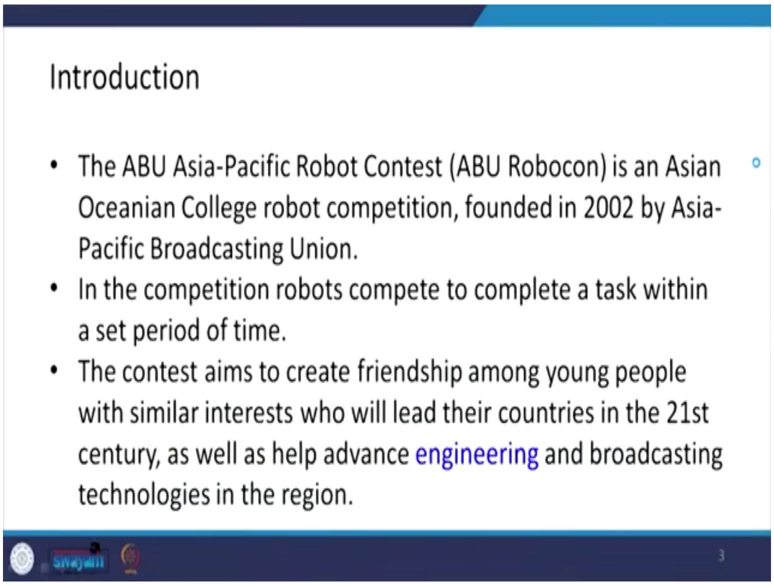

This ABU Asia pacific robot contest that is ABU Robocon which is called in short is an Asian Ocean College robot competition founded in 2002 by Asia-Pacific Broadcasting Union. In the competition, robots compete to complete a task within a set period of time, usually 3 minutes. The contest aims to create friendship among young people with similar interests who lead their countries in the 21st century, as well as help advance engineering and broadcasting technologies in the region.

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The event is organized by different countries each year in which they set up a problem statement for which one team from each country goes to the international to compete against other countries teams. So, this is how it is.

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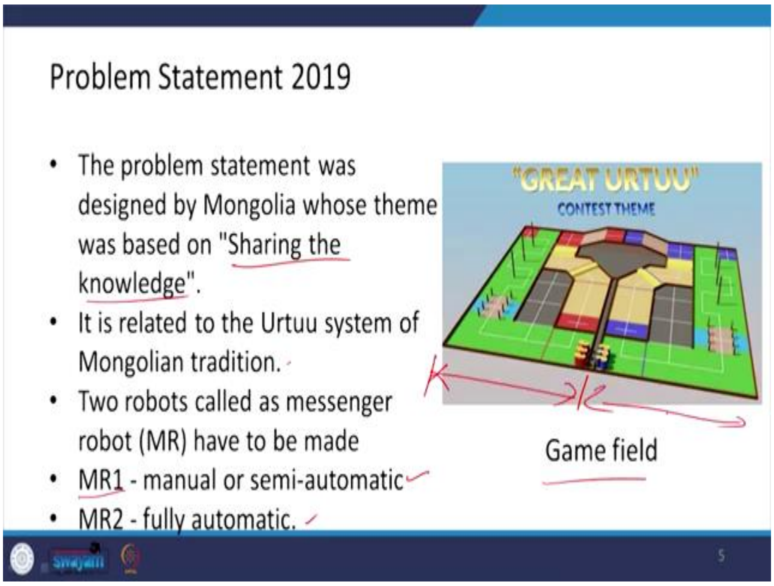

The problem statement for 2019, so I am going to discuss the problem statement for 2019 what was the task for this what were the various task that was to be performed by the teams. And how the IIT Roorkee team developed the two bots, that is, the manual as well as the automatic bot, and all the technologies involved in it, I will be discussing over here. That is the integration of the complete mechatronic system. In this lecture, I will be talking mostly about the manual robot, and next lecture, I will be talking about the autonomous robot. So, the problem statement for 2019 was designed by Mongolia, whose theme was sharing knowledge. It is related to the Urtuu system of Mongolian tradition, and the two robots called messenger have to be made. One robot that is MR1 is the manual semi-automatic, and MR2 is fully automatic. This is the game field you can see over here. The game field is divided into two sides for one team, each of which is going to compete.

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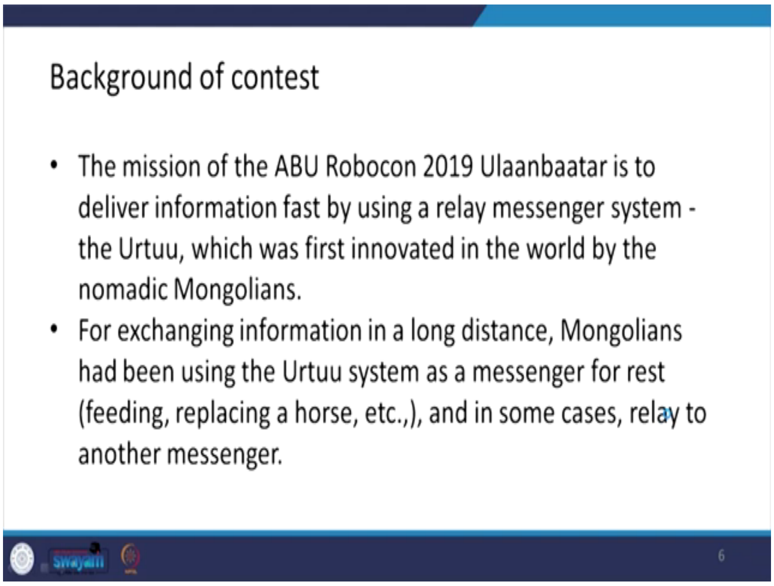

If we look at a little detail about this problem statement, so, the mission for this ABU Robocon 2019, Ulaanbaatar, is to deliver information fast by using a relay messenger system which they call Urtuu, and it was first innovated in the world by the nomadic Mongolians. For exchanging information in a long-distance Mongolians had been using this system as a messenger for rest. Feeding, replacing a horse, etcetera, and in some cases relay to another messenger.

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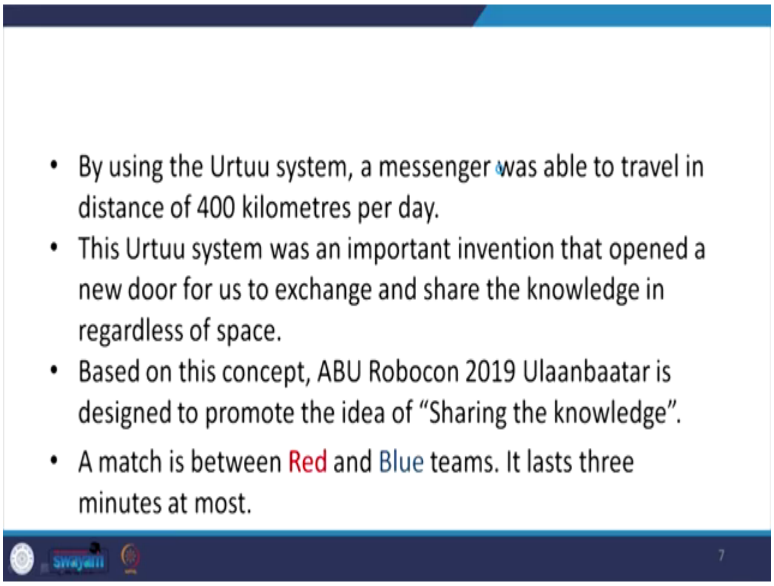

By using the Urtuu system, the messenger was able to travel a distance of 400 kilometers per day. And this Urtuu system was an important invention that opened a new door for us to exchange and share knowledge regardless of space. Now, so based on this Urtuu system, the problem statement for ABU Robocon 2019 was designed. And as I said, the theme was the sharing of knowledge. So, the match is contested between the two teams, that is the red and blue team, and at last the 3 minutes at the most. So, usually, the ABU Robocon problem statements, the duration of time given is 3 minutes.

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This is what the game field looks like. You have Khangai Urtuu over here. Then as I said, there are two zones here. So, this is a Khangai area. Then, you have Gobi Urtuu, Gobi area, and mountain Urtuu mountain area, and this is the Uukhai zone where finally, the autonomous robot has to go. So, and this is the throwing zone, this is the landing zone, and of course, this is the path through which this has to travel. So, this is what this terrain looks like. It goes through the forest and bridges over here, and for the manual bot and for the autonomous bot, it has to go through the sand dunes, tussock, and a mountain before finally landing over the Uukhai zone.

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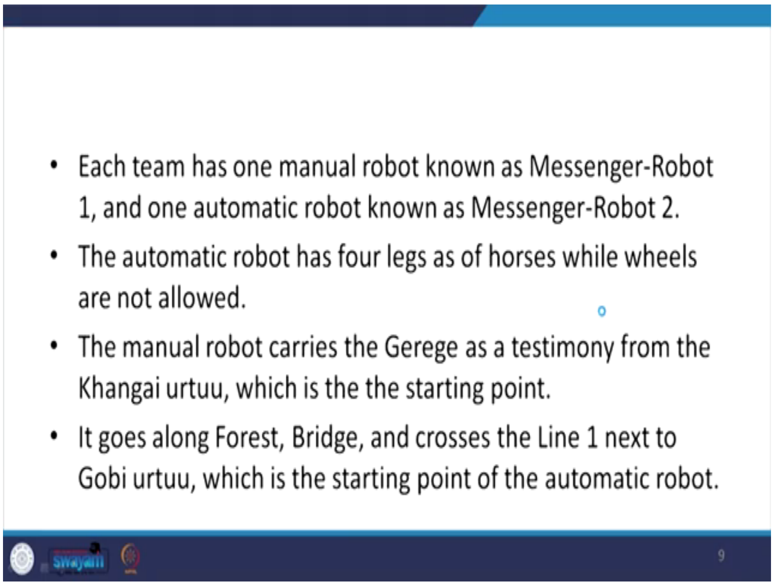

Each team has one manual robot known as Messenger-Robot 1 and one automatic robot known as Messenger-Robot 2. The automatic robot has 4 legs like horses, while wheels are not allowed. I will be discussing the design or development of the four-legged robot during my last lecture of this course, where I will be talking about the mechatronic design of 4 legged robots further from the basic. So, those who are interested can see that lecture as well. The manual robot carries the Gerege as a testimony from the Khangai urtuu, which is the starting point. It goes along forest, bridges, bridges and crosses line 1 next to the Gobi urtuu, which is the starting point of the automatic zone. So, this is how the manual robot has to come over here, and this is the starting point for the automatic robot.

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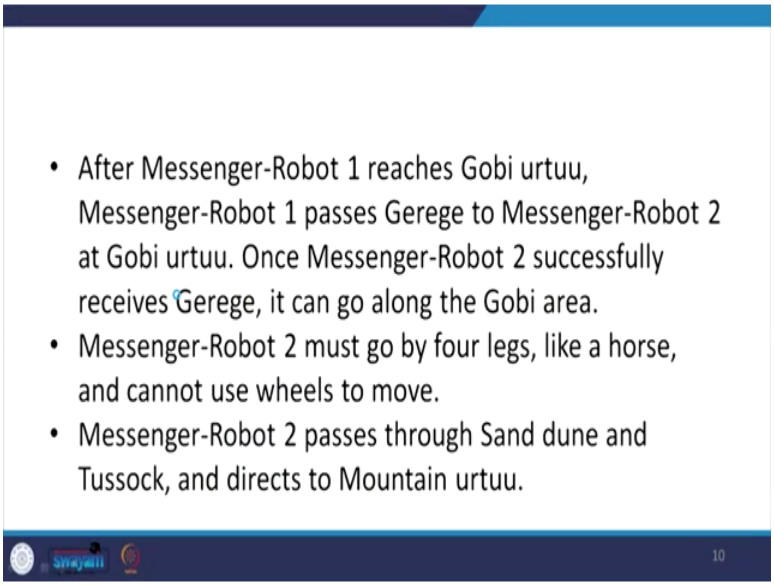

Now, after Messenger-Robot 1 reaches Gobi urtuu, Messenger-Robot 1 passes a Gerege to Messenger-Robot 2 at Gobi urtuu. And once Messenger-Robot successfully receives Gerege, it can go along the Gobi area. Messenger-robot 2 must go by four legs like a horse and cannot use wheels to move. So, this is the constant which was given by the organizing committee for the design of the automatic bot. The Messenger-Robot 2 passes through sand dunes and tussock and directs to mountain urtuu. After Messenger-Robot 2 reaches mountain urtuu, Messenger-Robot 1 can enter the throwing zone to throw Shagai and must earn 50 or more points. In case Messenger-Robot 1 earns 50 or more points, Messenger-Robot 2 is allowed to climb the mountain. Afterward, if it reaches the Uukhai zone and raises the Gerege first, the team is the winner, which is called Uukhai.

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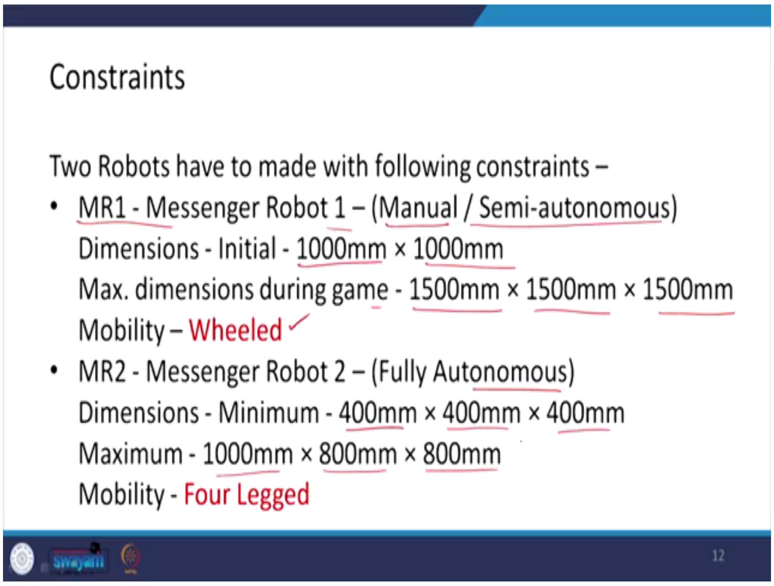

The constraints are given for these two robots are following. The two robots have to be made with the following constraints. Messenger-Robot 1 has to be manual or semi-autonomous, its dimension 1000 mm to 1000 mm. And initial maximum dimension during the game is 1500 mm to 1500 mm, and the mobility has to be on wheels only.

Messenger-Robot 2 is fully autonomous. Its dimensions minimum is 400 mm into 400 mm, maximum is 1000 mm into 800 mm, and the mobility is the with the help of the four legs.

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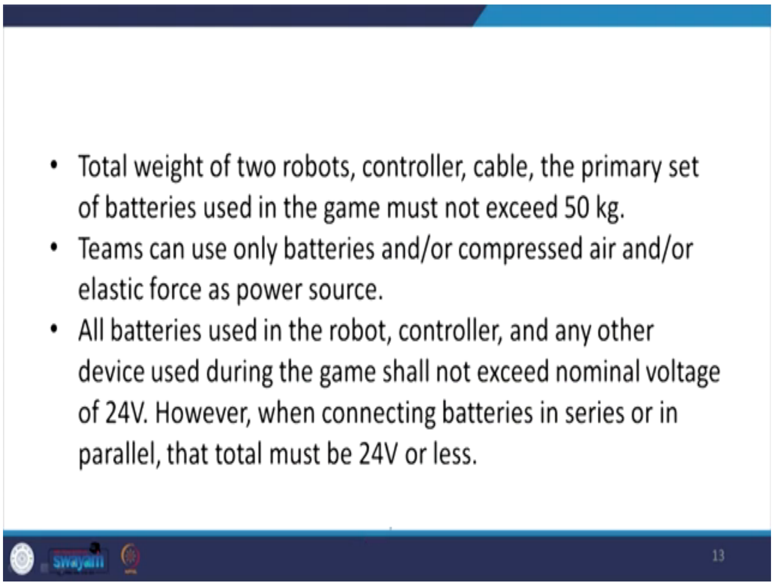

The total weight of two robots, controller, cables, the primary set of batteries used in the game must not exceed 50 kg. The team can use only batteries and or compressed air and or elastic force as the power source. All batteries used in the robot, controller, or any other device used during the game should not exceed a nominal voltage of 24 volts. However, when connecting batteries in series or in parallel total must be 24 volts or less.

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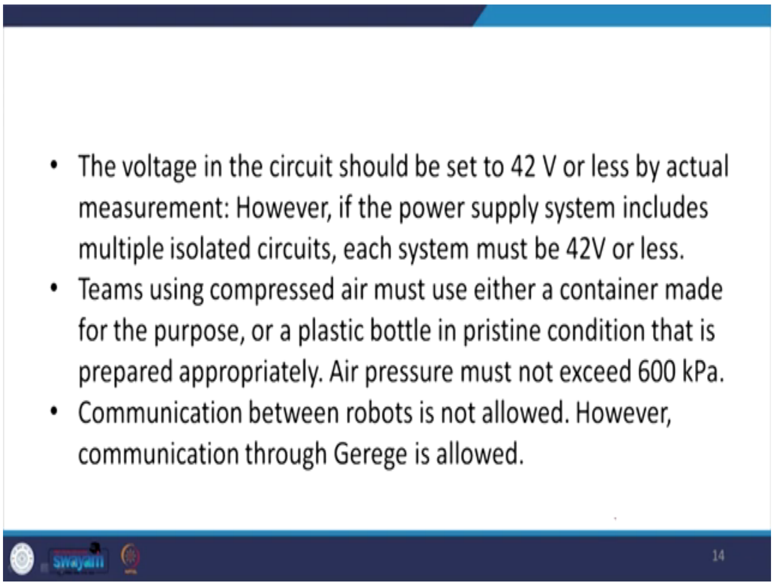

The voltage in the circuit should be set to 42 volts or less by actual measurement. However, if the power supply system includes multiple isolated circuits, each system must be 42 volts or less. Teams using compressed air must use either a container made for the purpose or a plastic bottle in pristine condition that is prepared appropriately. Air pressure must not exceed 600 kPa. Communication between robots is not allowed. However, communication through Gerege is allowed.

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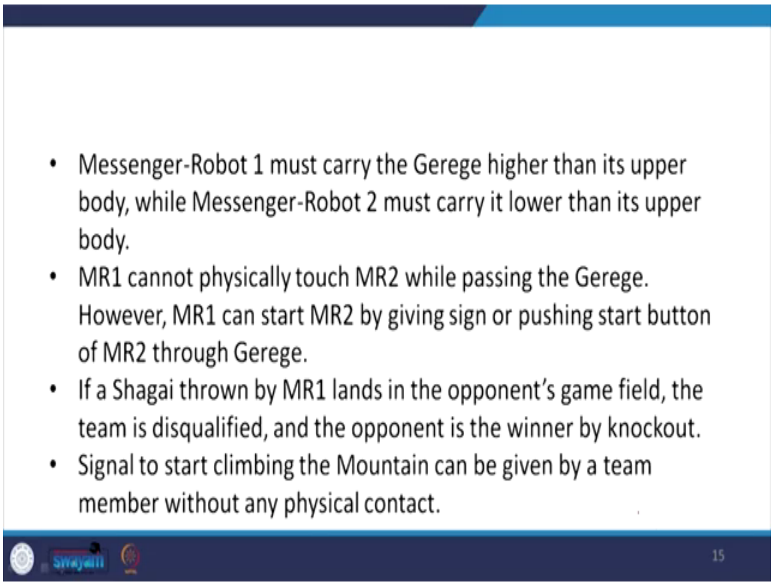

Messenger-Robot 1 must carry the Gerege higher than its upper body, while messenger-Robot 2 must carry it lower than its upper body. Messenger-Robot 1 cannot physically touch Messenger-Robot 2 while passing the Gerege. However, Messenger-Robot 1 can start Messenger-Robot 2 by giving a sign or by pushing the start button of Messenger-Robot 2 through Gerege.

If a Shagai thrown by Messenger-Robot 1 lands in the opponent's game field, the team is disqualified, and the opponent is the winner by knockout. Signal to start climbing the mountain can be given by a team member without any physical contact. So, here is the Messenger-Robot 1, so you can see the design and the prototype of that which was developed by the IIT Roorkee team.

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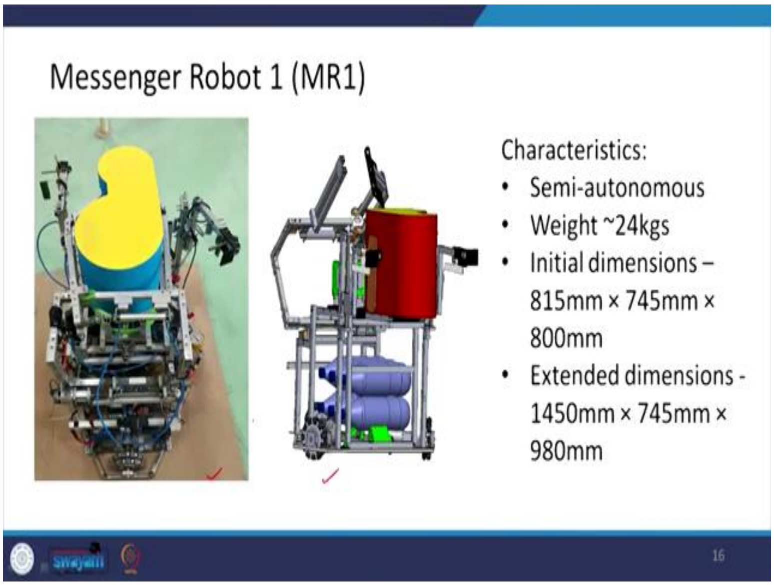

Its characteristic is semi-autonomous, weight is 24 kg. Initial dimension 815 mm into 745 mm into 800 mm and extended dimensions are 1450 mm into 745 mm into 980 mm.

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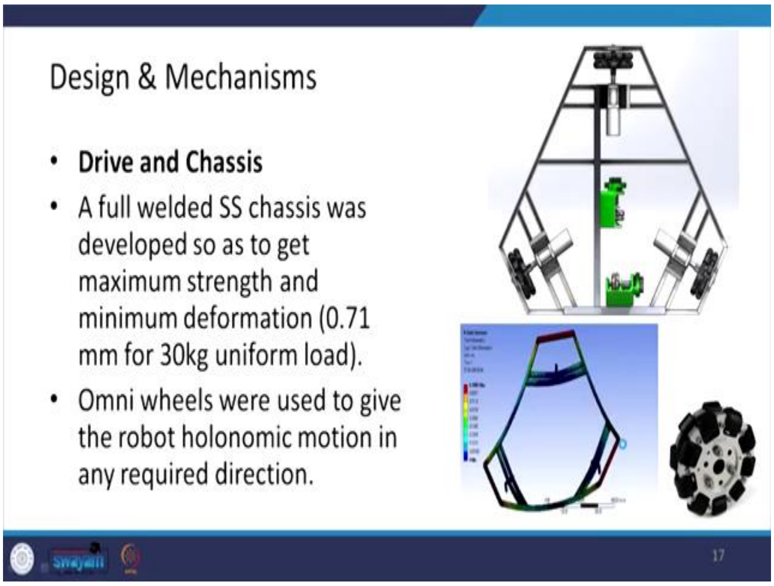

Looking at the design and mechanism of it, first, let us look at the drive and chassis. So, the team carried out an extensive FE analysis before fabricating the chassis. So, a fully welded stainless steel chassis was developed so as to get the maximum strength and minimum deformation 0.71 millimeters for 30 kg uniform load, and Omni wheels were used to give the robot a holonomic motion in any required direction. Then, actuator and sensors which were used 18-volt planetary geared of gear ratio 38:1 DC motor.

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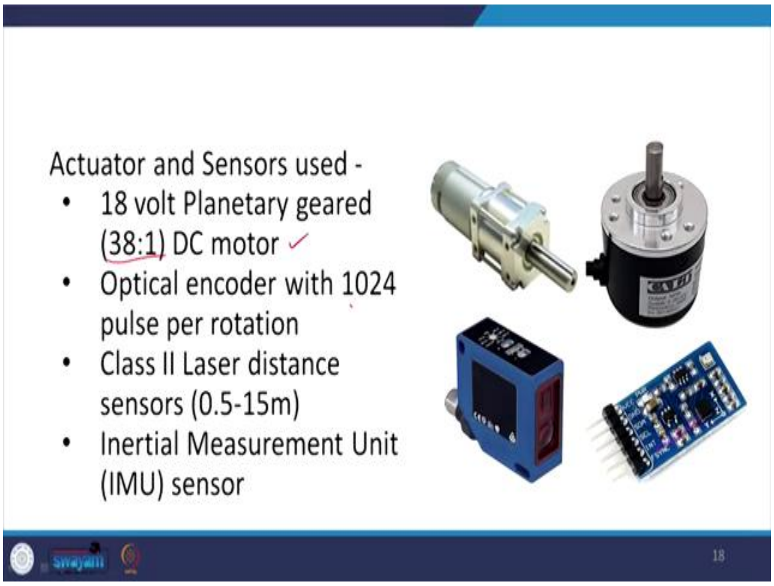

An optical encoder with 1024 pulse per rotation was used. Class II laser distance sensor, 0.5 to 15-meter range was used, and inertial measurement unit IMU sensor was used.

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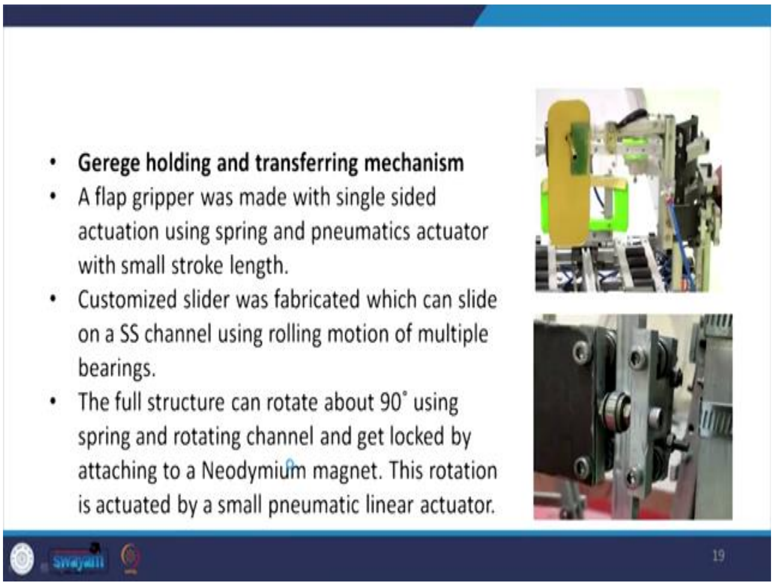

Gerege holding and transferring mechanism: It consists of a flap gripper that was made with a single-sided actuation using spring and pneumatic actuator with small stroke length. A customized slider was fabricated, which can slide on a stainless steel channel using the rolling motion of multiple bearings. The full structure can rotate about 90^0 using spring and rotating channel and get locked by attaching to a neodymium magnet. This rotation is actuated by a small pneumatic linear actuator.

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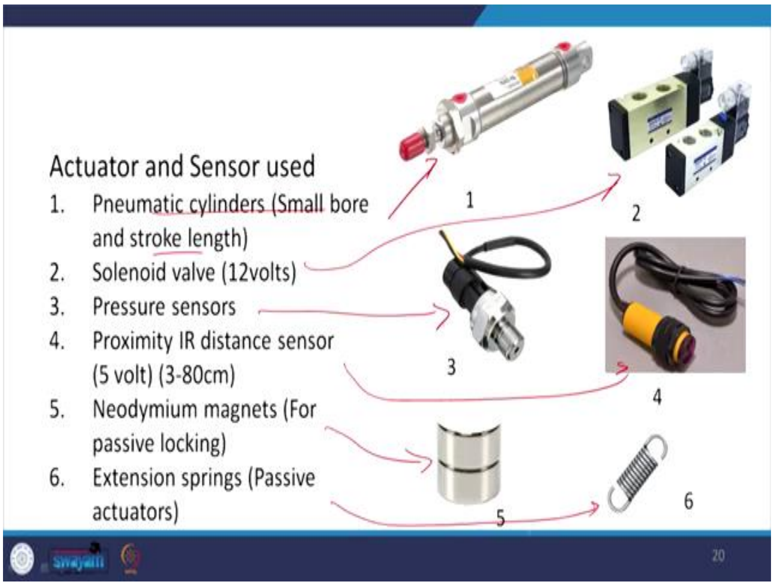

Actuators and sensors are used where a pneumatic cylinder, small-bore, and stride length, this one. A solenoid valve operated by 12 volts, pressure sensor, proximity IR distance sensor, neodymium magnet for passive locking, and extension spring for the passive actuation.

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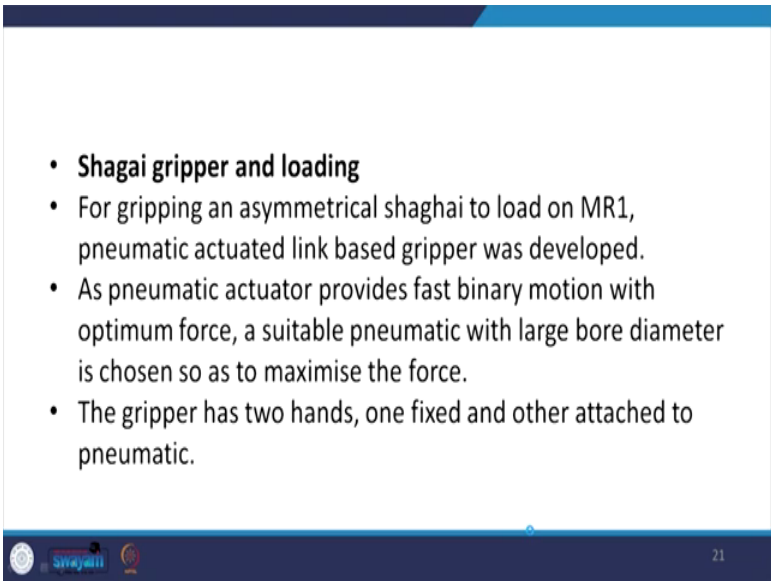

Shaghai gripping and loading: For gripping and asymmetric Shaghai to load on Messenger-Robot 1, a pneumatically actuated link-based gripper was developed. As a pneumatic actuator provides fast binary motion with optimum force, a suitable pneumatic with a large bore diameter is chosen so as to maximize the force. The gripper has two hands, one fixed and the other attached to the pneumatic.

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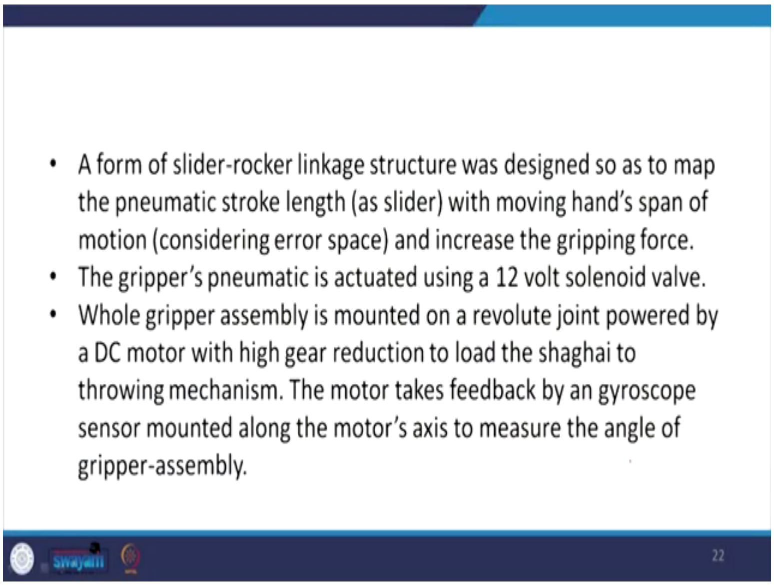

A form of slider-rocker linkage structure was designed so as to map the pneumatic stroke length with moving hand's span of motion and increase the gripping force. The gripper pneumatic is actuated using a 12-volt solenoid valve, as I told you earlier. At the same time, a gripper assembly is mounted on a revolute joint powered by a DC motor with a higher gear reduction to load the Shaghai to the throwing mechanism. The motion of the motor takes feedback by a gyroscope sensor mounted along the motor's axis to measure the angle of the gripper assembly. Here are the actuators and sensors used here. 18 volt DC motor of gear ratio 125:1, planetary gear reduction was used. Pneumatic 1-inch bore and gyroscopic sensor single axis with $\pm 300^0/sec$.

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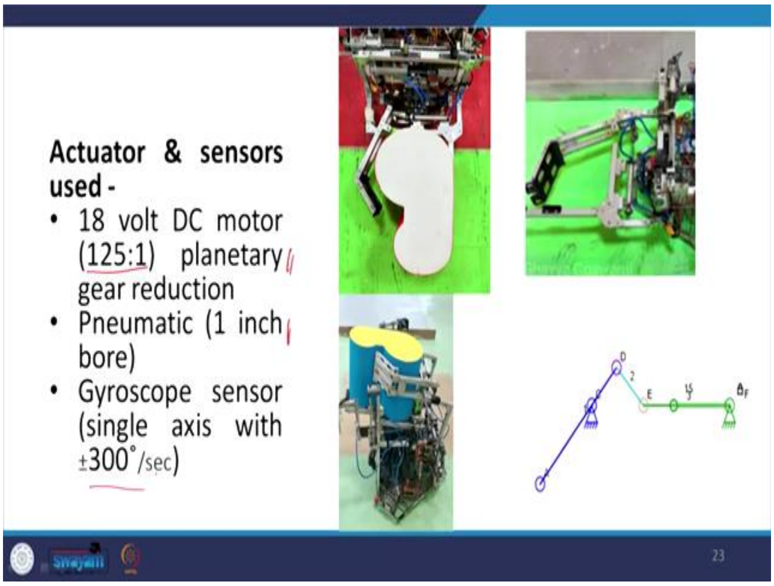

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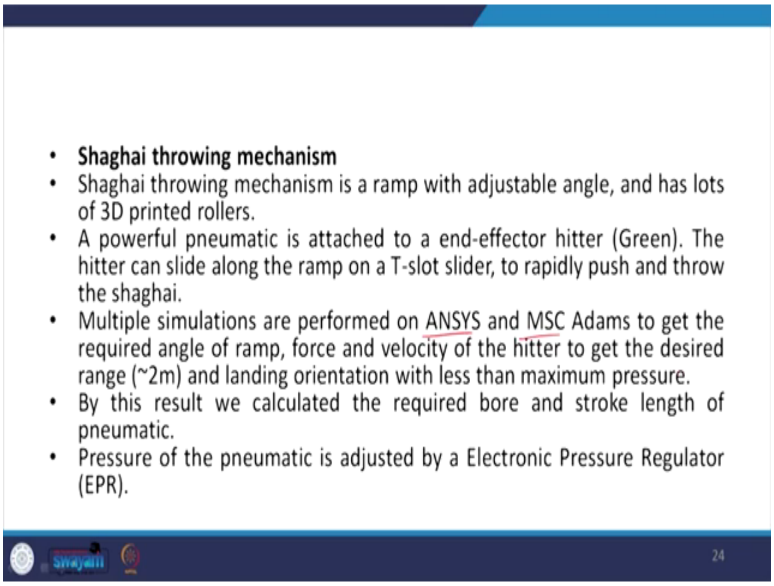

Next, let us look at the Shaghai throwing mechanism. The Shaghai throwing mechanism is a ramp with adjustable gain and a lot of 3D printed rollers. A powerful pneumatic is attached to the end hitter. The hitter can slide along the ramp on a T-slot slider to rapidly push and through the Shaghai. Multiple simulations were performed on ANSYS and MSC Adams to get the required angle of the ramp, force, and velocity of the hitter to get the desired range, that is, the throwing of the Shaghai 2 meter and landing orientation with less than maximum pressure. By this result, we calculated the required bore and stroke length of the pneumatic, and the pressure of the pneumatic is adjusted by an electronic pressure regulator.

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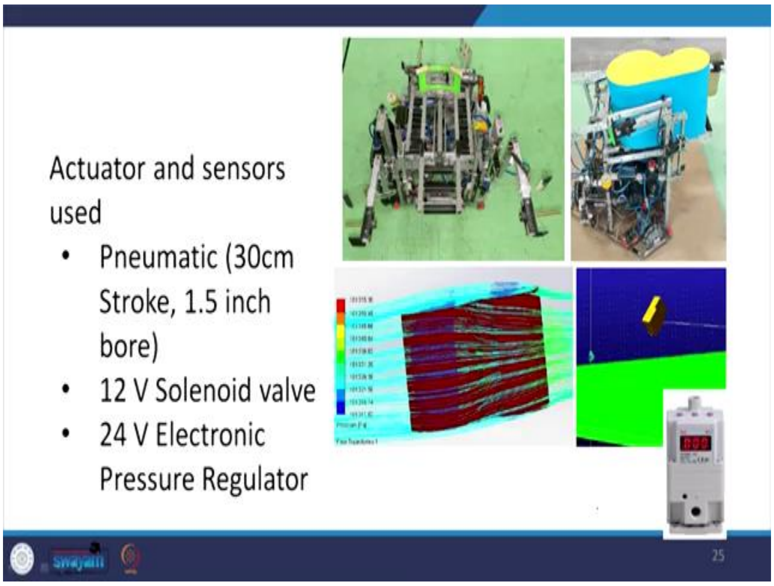

The actuator and sensors used here were the pneumatic, with 30-centimeter stroke, 1.5-inch bore. 12-volt solenoid valve, 24-volt electronic pressure regulator.

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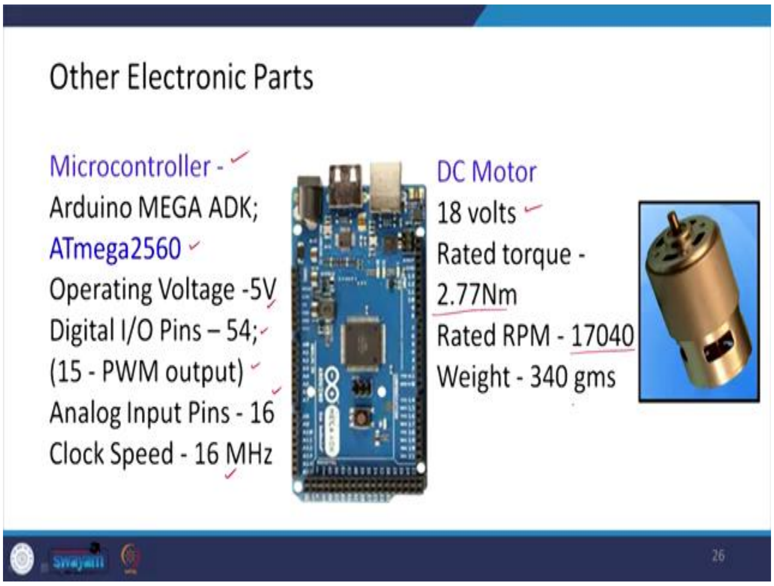

Other electronic parts used were the microcontroller that is Arduino MEGA ADK, ATmega 2560, which has got an operating voltage minus 5 volts. Digital input-output pin 54, 15 PWM pulse width modulation output. Analog input pin 16, clock speed 16 MHz.

And the DC motor is 18 volt, rated torque is 2.77 Nm, rated RPM 17040, and weight around 340 grams.

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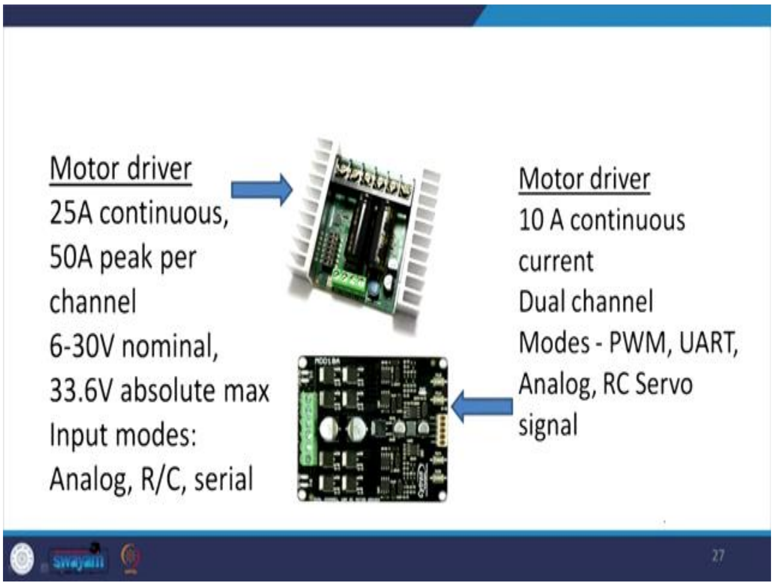

The motor driver is a 25 ampere continuous, 50-ampere peak per channel that is what its capability is, 6 to 30-volt nominal and 33.6-volt absolute maximum is there input modes are there, an analog R/C, as well as the serial, are there. And another motor driver used was of 10-ampere continuous current, a dual-channel, a modes PWM, UART, analog, R/C servo signal.

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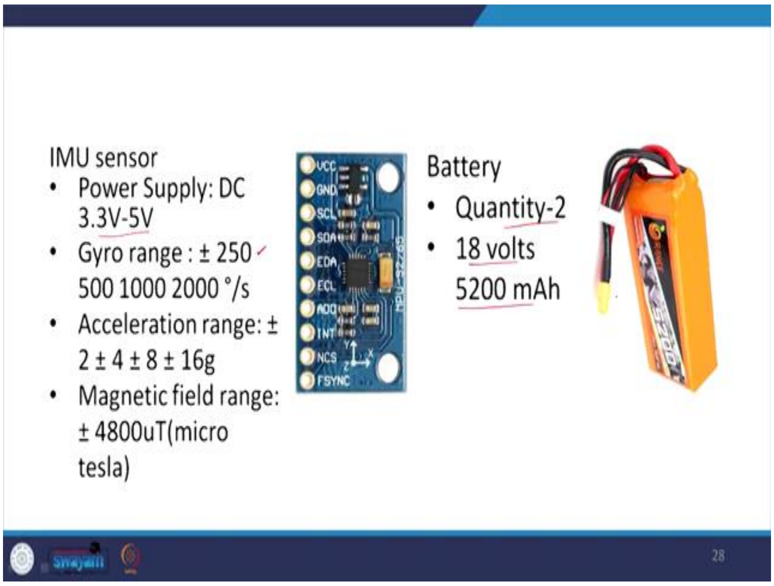

Then IMU sensor used has a power supply DC 3.3 volt to 5 volts. Gyro range 250, 500, 1000, 2000 degrees per second. Acceleration range ± 2, ± 4, ± 8, or ± 16 g. Magnetic field range 4800 microtesla. And the two batteries of 18 volts, 5200 mAh, were used.

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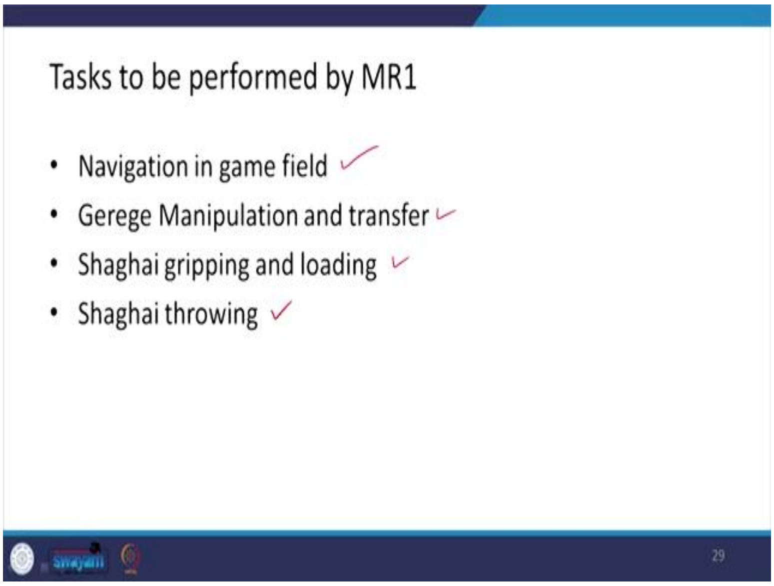

Now, let us look at what tasks were to be performed by a Messenger-Robot 1. So, the first task of the Messenger-Robot 1 is to navigate in the game field. Then the second task is the Gerege manipulation and transfers to the autonomous bot, then the Shaghai gripping and loading, and the Shaghai throwing. So, these four tasks were supposed to be performed by Messenger-Robot 1. So, let us look at the first task navigation in the game field. So, now the IIT Roorkee team accomplish this?

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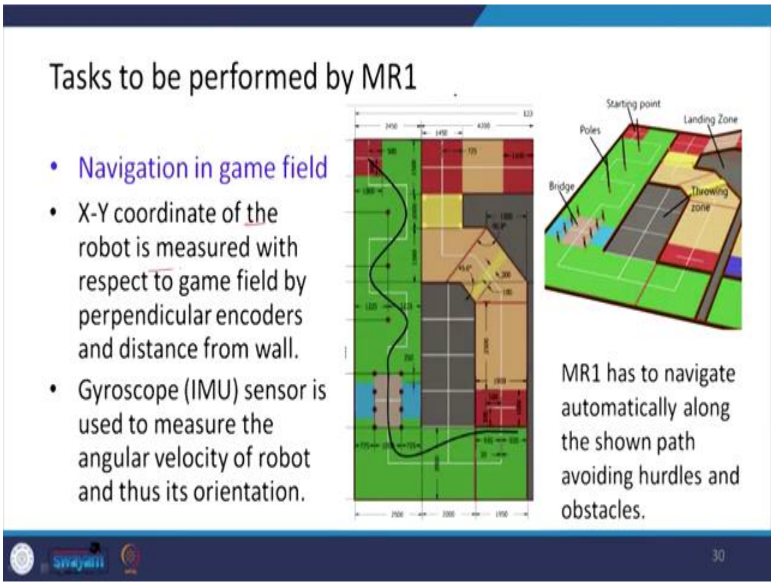

So, the X-Y coordinate of the robot is measured with respect to the game field by perpendicular encoders and distance from the wall. Then, a gyroscope IMU sensor is used to measure the angular velocity of the robot and thus its orientation. MR1 has to navigate automatically along the shown path avoiding hurdles and obstacles. So, this is how this MR1 has to navigate in the game field.

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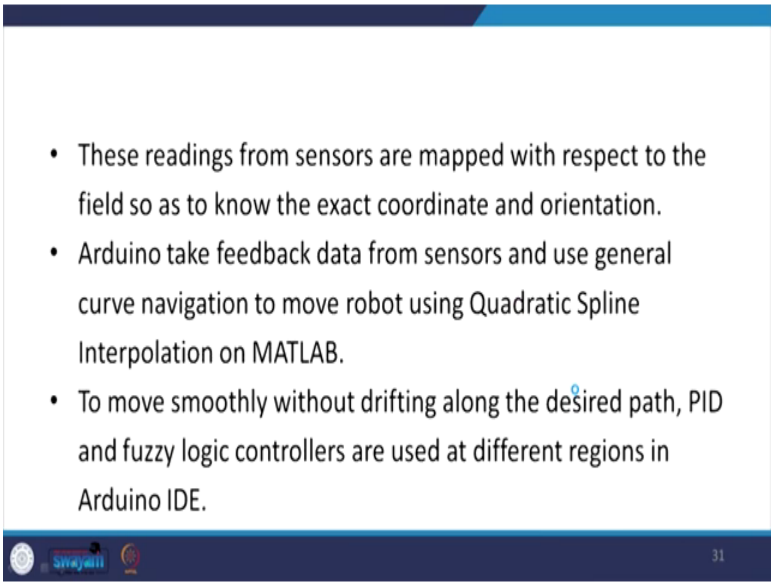

Then, the readings from sensors are mapped with respect to the field so as to know the exact coordinate and orientation. Arduino takes feedback data from sensors and uses general curve navigation to move the robot using a quadratic spline interpolation on MATLAB. To move smoothly without drifting along the desired path, PID and fuzzy logic controllers are used at the different regions in the Arduino IDE.

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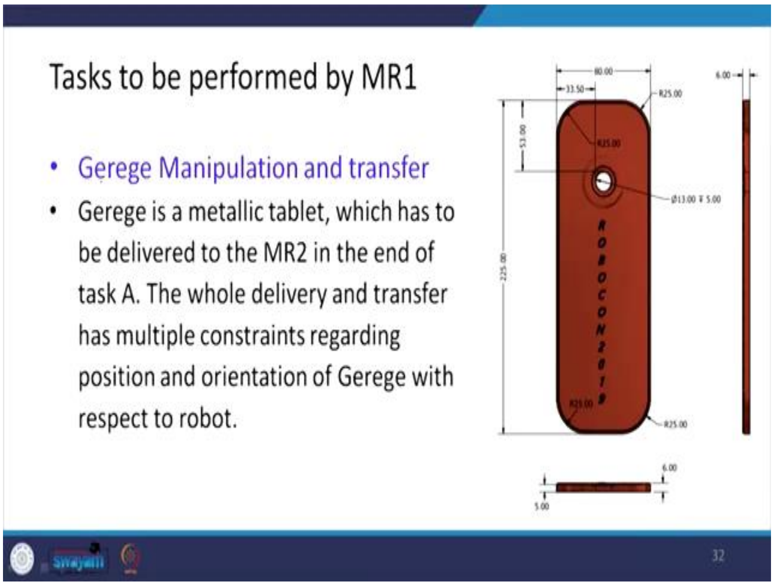

Then next, look at the second task to be performed by the Messenger-Robot 1, which is the Gerege manipulation and transfer. So, a Gerege is a metallic tablet, which has to be delivered to the Messenger-Robot 2 at the end of the task. The whole delivery and transfer have multiple constraints regarding the position and orientation of the Gerege with respect to the robot.

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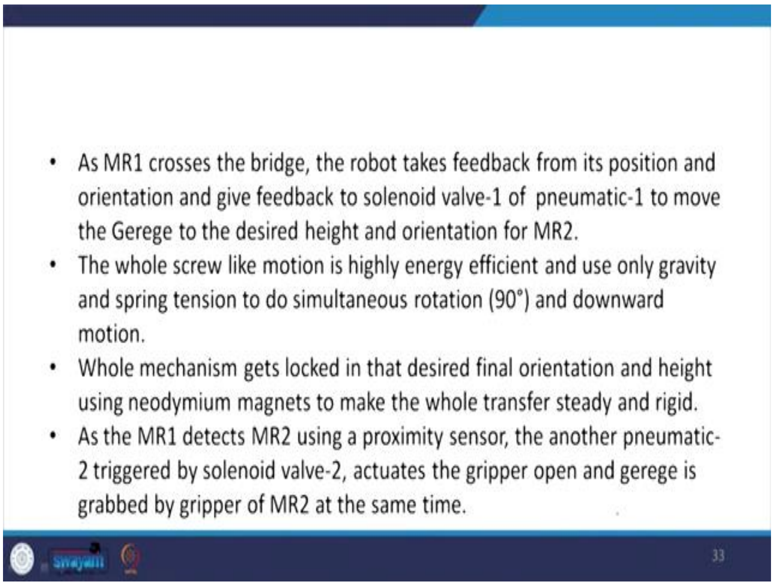

As MR1 crosses the bridge, the robot takes feedback from its position and orientation and gives feedback to the solenoid valve-1 of the pneumatic-1 to move the Gerege to the desired height and orientation for the Messenger-Robot 2. The whole screw-like motion is highly energy-efficient and uses only gravity and spring tension to do simultaneous rotation and downward motion. The whole mechanism gets locked in the desired final orientation and height using a neodymium magnet to make the whole transfer steady and rigid. As the MR1 detects MR2 using a proximity sensor, another pneumatic-2 triggered by solenoid valve-2 actuates the gripper open, and Gerege is grabbed by the gripper of MR2 at the same time. Then let us look at the third task to be performed by the Messenger-Robot 1, that is, the Shaghai gripping and loading.

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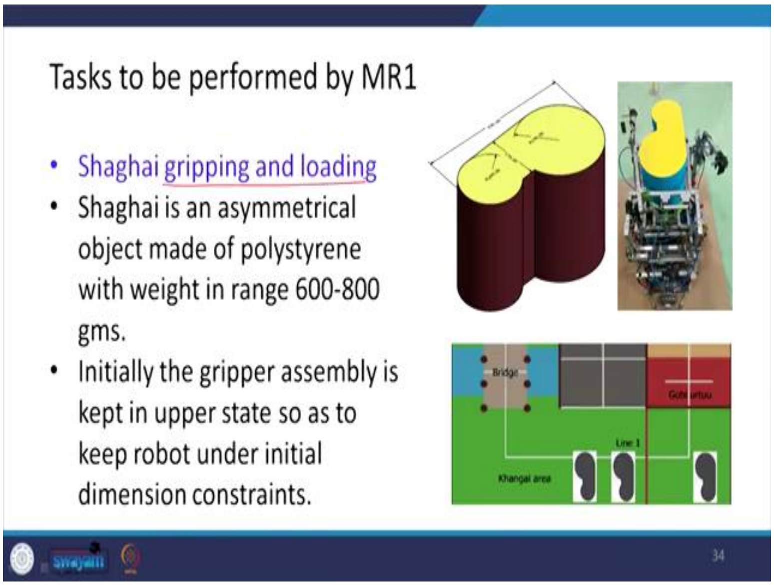

This Shaghai is an asymmetrical object, as you can see over here. And it is made of polystyrene with a weight in the range of 600 to 800 grams. Initially, the gripper assembly is kept in the upper state so as to keep the robot under initial dimension constraint.

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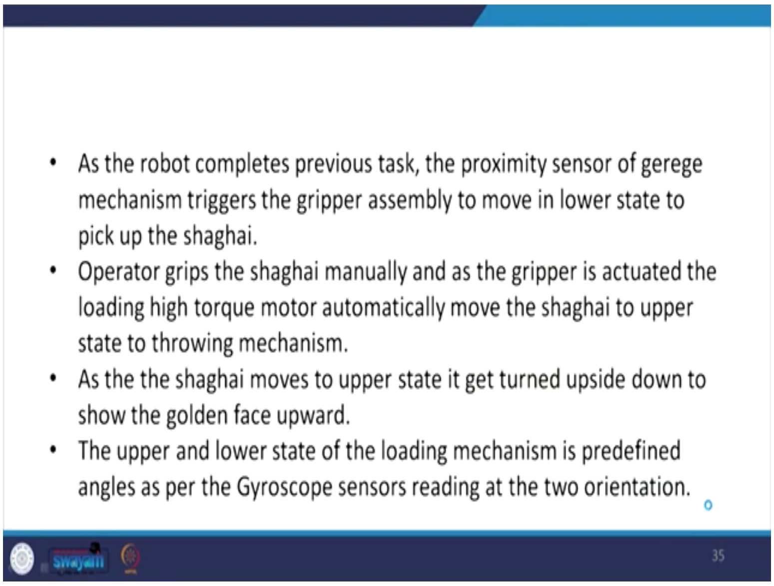

Then, as the robot completes previous tasks, the proximity sensor of the Gerege mechanism triggers the Gerege assembly to move in the lower state to pick up the Shaghai. The operator grips the Shaghai manually, and as the gripper is actuated, the loading high torque motor automatically moves the Shaghai to the upper state to the throwing mechanism. As the Shaghai moves the upper state, it gets turned upside down to show the golden face upward. The upper and lower state of the loading mechanism is a predefined angle as per the Gyroscope sensor of reading at the two orientations.

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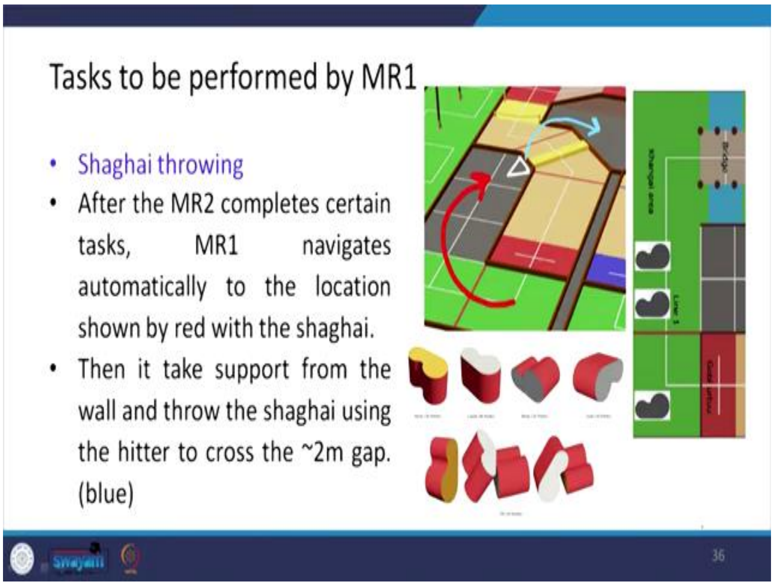

Then, the next task, or rather the last task to be performed by the Messenger-Robot 1 is the Shaghai throwing. Now, after the MR2 completes a certain task, MR1 navigates automatically to the location shown by red with the Shaghai that is at this position, and from here, this is thrown. Then it takes support from the wall and throws the Shaghai using the hitter to cross that 2-meter gap.

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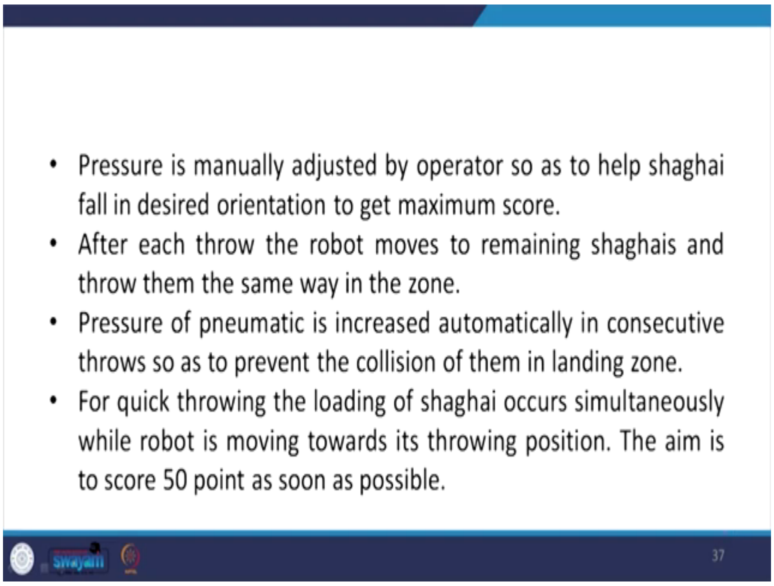

Now, pressure is manually adjusted by the operator so as to help Shaghai fall in the desired orientation in order to get the maximum score. After each throw, the robot moves to the remaining Shaghai and throws them the same way in the zone. The pressure of pneumatic is increased automatically in consecutive throws so as to prevent the collision of them in the landing zone. For quick throwing, the loading of Shaghai occurs simultaneously while the robot is moving towards the throwing position. The aim is to score 50 points as soon as possible.

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So, this is the team Robocon, IIT Roorkee for 2018-19, and this team was given the Judges Special Award for the event.

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I would like to thank the faculty advisor of the Robocon team, Professor Shailesh Ganpule, as well as all the members of this team from the 3rd year, 4th year, and 2nd year.

Thank you.