Control Award Content Sheet

Please turn in this sheet during your Judge Interview along with your Engineering Notebook

Team #: 4717 **Team Name: Mechromancers**

Autonomous objectives: Our autonomous is designed to score the maximum number of points when starting from ether of the two starting locations. We are capable of starting in the hanging position where we proceed to land and sample the gold mineral. We then proceed to deliver the team marker to the Depot. While driving, we make sure to avoid all loose particles on the field to avoid penalties. After delivering the team marker, we proceed to the crater and park inside it.

Sensors used:

Type	Qty	Description
Laser Range Sensor	1	2m laser range sensor, used to sense the location of the wall when driving
Optical Interrupter	2	Determine position of arms during calibration
Magnetic Encoder	5	Encoders built into dc motors. Used to detection angular position and speed
Hall Effect Sensor	1	Position sensor used to detect the position of the hook
IMU (internal measurement unit)	1	Determine robot heading (degrees) Determine robot pitch (degrees)
Web Camera	1	Common web camera used as a Machine Vision Sensor

We use a verity of sensors on our robot to control all aspects of operation. Our robot is designed to have capabilities that would make it very hard for a human operator to provide adequate control without computer assistance.

Our two large wheels make the robot unstable and require stabilizing arms for balance. The position of these arms must be constantly controlled to maintain the proper chassis angle relative to the ground. Each arm contains an Magnetic Encoder that reports the angle of the arm. The front and back angles, along with some basic trigonometry allow the overall chassis angle to be properly maintained. The IMU also helps determine the current angle of the chassis using built-in gyroscopes, accelerometers and magnetometers to fuse together both dynamic movements along with the earth's gravitational force.

When releasing our hook from it's hang position, we must make sure the hook has actually released. To sense this release, we attached a magnet to the hook and used a Hall Effect Sensor to check for the presence of a magnetic field. This allows us to have a failsafe in that we are able to retry the hook detachment until success.

The Laser Range Sensor is used to determine the distance to the wall as we approach in autonomous. This allows us to slow down and sense the wall accurately.

Sensors used (cont):

The web camera is used along with the Tensor Flow machine vision library to detect the two types of minerals (silver ball, gold block). The camera is trained using thousands of images of the balls and cubes in various orientations. This data can then be used to allow accurate detection.

In any system with computer controlled movable objects, you need a way to determine the initial position of the object. For our wheels, we are able to zero the encoders at startup and provide a known position. Gravity and magnetic fields provide a know reference for our IMU. Our arms have a problem in that during the transition from Autonomous to Teleoperation, we don't know their final position. To overcome this problem, we use a Optical Interrupter on each arm to calibrate the arms to a know position. A small flange is attached to the arm in a known location and the optical interrupter can sense when this flange rotates and breaks the light beam.

Key algorithms:

NOTE: All of our programs use the common PID (proportional, integral, derivative) control algorithm internally. This algorithm allows the computer to provide a proper output to reduce an error it senses. It basically measures an error and multiplies this error by a P constant to obtain an output. This output is then applied to hopefully reduce the error. If there is still an error after applying the P, an integral(sum) can be taken of the error over time and used with the I constant to provide an additional output to reduce the error. During this, the derivative (rate of change) can be calculated and when scaled by the D constant can be used to control any oscillation that might occur.

The machine vision algorithm "Tensor Flow" is used during autonomous to detect the particles position and classify them as silver or gold minerals. We use this algorithm along with our own program to determine which position the single gold mineral is in relative to the other two silver minerals. There are a lot of cases to handle since the detection algorithm returns not only the three particles in question but also the position of all of the other particles in the crater. The algorithm needs to filter out these bad particles and be able to focus on the three primary ones. By using a number of failsafe measures, we have achieved a 99% detection rate of the proper gold particle.

We use a complex algorithm to maintain the angle of the chassis while shooting. In order for us to accurately shoot the silver particles into the lander we need the chassis to be at a 3.7 degree angle to the floor. The IMU is used to read this pitch angle 50 times a second and then the arms are adjusted to the proper position to maintain this angle. We use a PID controller on each arm to control their local position, along with a global PID controller controlling the main chassis angle. At the same time, another PID controller is controlling the speed and a forth is controlling the robot steering angle.

We also have the following algorithms:

- Control shooter cocking and firing motor position
- Control robot driving speed and turning angle
- Independent BigWheel wheel notch positioning when entering the crater
- Control robot deploy and hang positions, stretch out arms and contort body to hang and unhook
- Arm calibration using optical interrupter. Rapid movement followed by slow and accurate positioning

Driver controlled enhancements:

Because of the inherently unstable design of our robot, it is very hard for a human to control. We employ a number of autopilot type enhancements to help the driver during teleoperation.

One main task is keeping the chassis balanced during hard driving and turning. The arms must be monitored and lowered to the proper position to maintain this angle at all times. The force applied must be calculated and varied depending on the amount of acceleration and deceleration the operator is applying. As you will see, this algorithm performs very will as there is little or no tilt on the chassis while driving.

Another task made easier is the task of holding the arms at a known position both when attempting to hang and also when entering the crater. This is accomplished using preset buttons on the joystick along with PID algorithms controlling each arm motor. This really reduces the workload while executing these tasks.

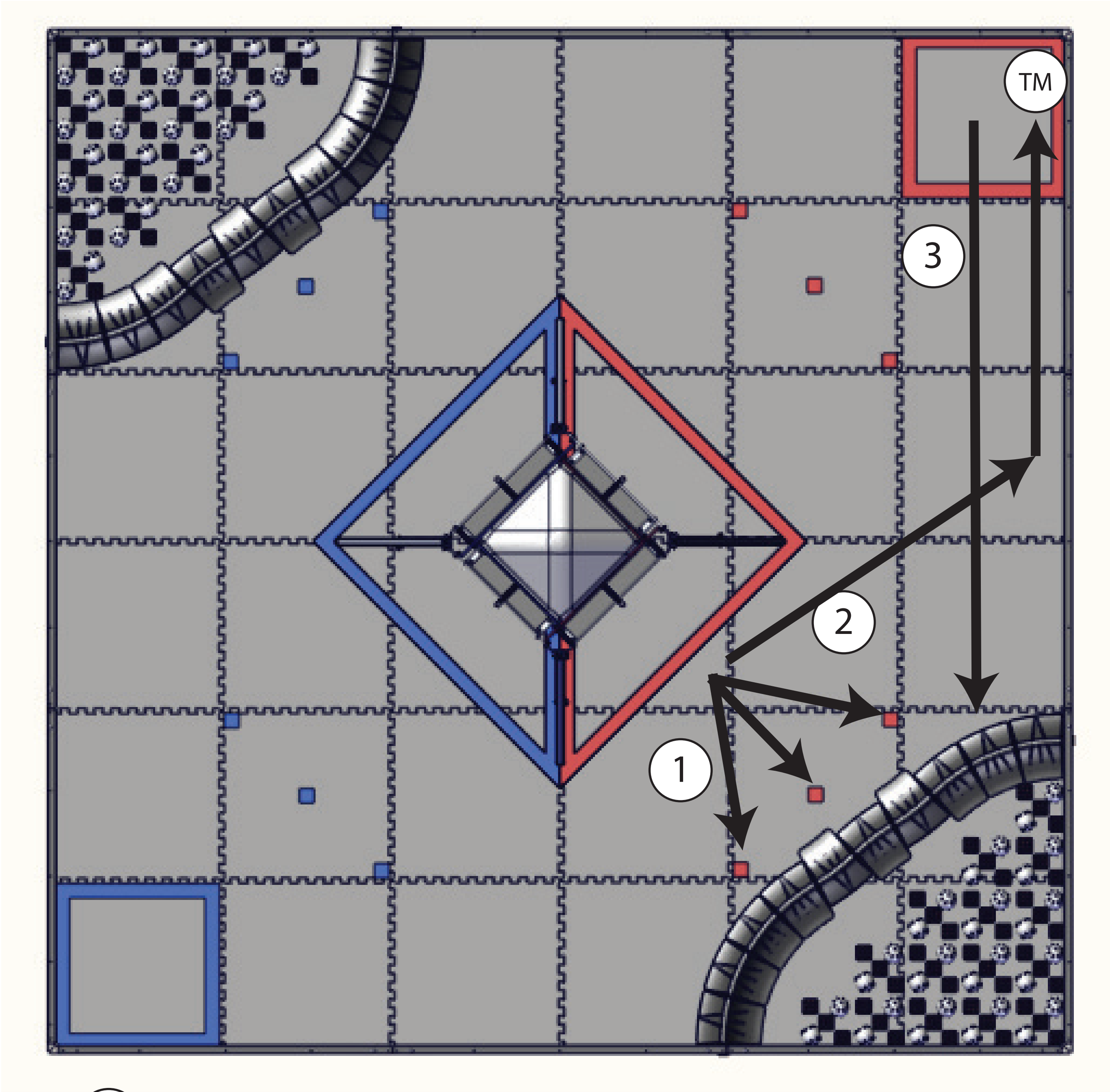
The addition of "one-button shooter aiming" has really improved the accuracy and ease of use during particle scoring. This would not be possible with out the integration of the IMU, distance and arm encoder sensors allowing a single button press to align the shooter with the lander. We are even experimenting with completely automated shooting using this capability.

Another driver controlled enhancement is the ability to automatically rotate each wheel into a synchronized position. This is needed to line up the notches in the wheels to we can drive into the crater easily. An algorithm calculates the current position of each notch on the wheels taking into account how far each has traveled since the robot was reset. Using this information, the wheels are commanded to rotate to the same position above the crater wall. Because there is a danger of accidentally turning one wheel into the crater before the other one is ready, if the notch is already close to the crater wall that particular wheel will not rotate.

Engineering notebook references:

- For more information on the PID algorithm used please see page 130 in the engineering notebook.
- The complete Tensor Flow machine learning algorithm used to detect and sample the particles is described starting on page 221 in the engineering notebook.
- A map of the joystick buttons used to enhance drive-ability is shown on page 228
- A description of the equations used to maintain the chassis angle using the arm angles is on page 204
- A description of the arm calibration algorithm along with the layout of the optical interrupter is on pages 218 and 210

Autonomous program diagrams: **RED Alliance, Crater Side**



1 Path taken to sample the minerals at the start of autonomous when hanging on the crater side. Sense using web cam/macine vision (20 sec)

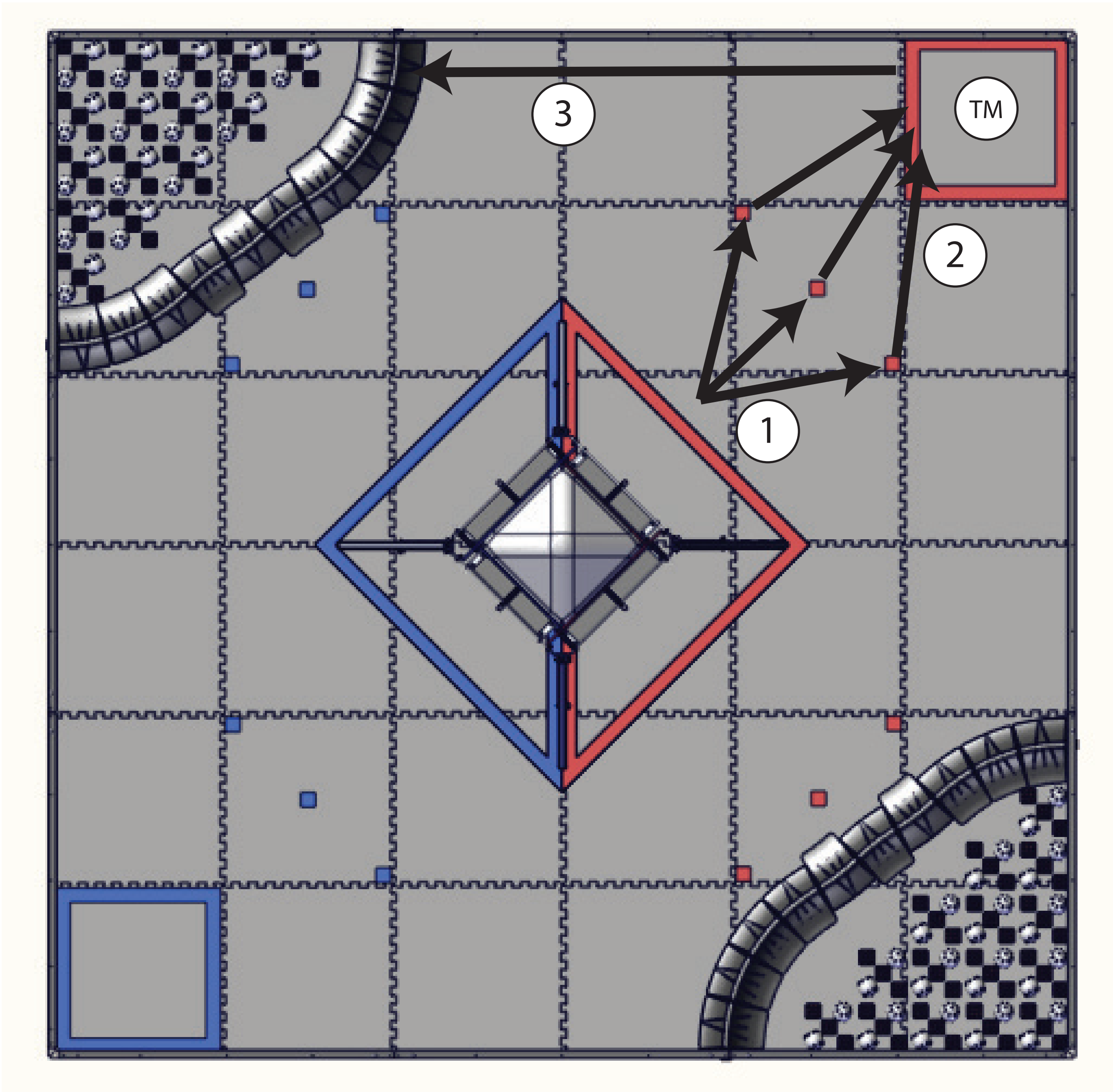
80 points

2 Path taken to manouver to drop off the team marker in the depot. Sense wall using distance sensor (7 sec)

3 Path taken to move into the crater at the end of autonomous. Arm sensor to maintain arm angle. (3 sec)

TM Position of team marker at the end of autonomous period

Autonomous program diagrams: Red Alliance, Depot Side



1 Path taken to sample the minerals at the start of autonomous when hanging on the crater side. Sense using web cam/macine vision (20 sec)

2 Path taken to manouver to drop off the team marker in the depot. Sense wall using distance sensor (4 sec)

3 Path taken to move into the crater at the end of autonomous. Arm sensor to maintain arm angle. (3 sec)

TM Position of team marker at the end of autonomous period

80 points