Control Award Sponsored by Arm Submission Form

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| **Team # 16290** | **Team Name: Z.I.P Ties** |

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| **Autonomous** | **Points** | **Description** |
| First | Maximum of 50 Auto points + 30 TeleOp points | 1. Score Pre-Loaded cone on far high Terminal (5 Auto points + 5 TeleOp points)  2. Pick up and score all 5 Cone Stack cones on far high Terminal (25 Auto points + 25 TeleOp points)  3. Navigate to designated Signal Zone based on Signal Sleeve (20 Auto points) |
| Second | Maximum of 50 Auto points + 30 TeleOp points | 1. Score Pre-Loaded cone on centerline high Terminal (5 Auto points + 5 TeleOp points)  2. Pick up and score all 5 Cone Stack cones on centerline high Terminal (25 Auto points + 25 TeleOp points)  3. Navigate to designated Signal Zone based on Signal Sleeve (20 Auto points) |
| Third | Maximum of 44 Auto points +  24 TeleOp points | 1. Score Pre-Loaded cone on medium Terminal (4 Auto points + 4 TeleOp points)  2. Pick up and score all 5 Cones on the Cone Stack on medium Terminal (20 Auto points + 20 TeleOp points)  3. Navigate to designated Signal Zone based on Signal Sleeve (20 Auto points) |
| Fourth | Maximum of 25 Auto points +  5 TeleOp points | 1. Score Pre-Loaded cone on high Terminal (5 Auto points + 5 TeleOp points)  2. Navigate to designated Signal Zone based on Signal Sleeve (20 Auto points) |
| **Sensors Used** | **Usage** | |
| 2 Dead-Wheel Odometers | Two Dead-Wheel Odometers with free-spinning omni wheels and Rev Through Bore Encoders are used to track the position of the robot during the autonomous period. By measuring the encoder values, the robot’s position and velocity is calculated, allowing the robot to move more accurately | |
| 1 Rev Magnetic Limit Switch | A Rev Magnetic Limit Switch is used to detect outtake rotation, allowing us to properly coordinate outtake actions. | |
| 2 Logitech C270 Webcams | A Logitech C270 webcam is used in Autonomous to detect the Signal Sleeve and determine the Signal Zone the robot needs to navigate to. Another webcam is used to guide the turret. | |
| 1 Inertial Measurement Unit | The Rev Control Hub’s Inertial Measurement Unit (IMU) is used to measure the robot’s angle during the TeleOp period. | |
| 4 Motor Encoders | Two motor encoders are used to control the intake linear slide and two are used to control the outtake linear slide. A custom Sigmoid function is used with the encoders to control these slides. | |

**Key Algorithms:**

**Odometry Localization:** Using the Odometry wheels, the robot’s position is tracked through the autonomous period. The rotational of each odometer wheel and the position of those wheels with respect to the robot used to calculate the robot’s change in position each loop. The odometer readings are first converted into the robot-centric change in position, which is transformed using matrix multiplication to calculate the field-centric change in position. This function is used throughout autonomous to track the robot and ensure accurate movement.

**Motion Profiling:** When controlling the robot, the first instinct is to directly set target powers to the motors. However, when starting or stopping the movement, this sudden shift in motor powers can create sudden shifts in the robot’s position. To ensure smoother movement, motion profiles are created, which create a target velocity and acceleration at different times in the movement. The acceleration of the robot is controlled using 7 sections, which contain phases of increasing, constant, and decreasing acceleration. The velocity is calculated by integrating the acceleration curve.

**Quintic Trajectory Genreration:** To ensure robust, non-linear movement in autonomous, we create a spline trajectory for the robot to follow. The trajectory is defined from a series of target points with a parametric curve between each point. These parametric curves are quintic along both the x and y dimensions. The coefficients of these quintic functions are determined using a system of six linear equations with the target position, velocity, and acceleration at both endpoints of that segment as the solutions. This trajectory can be passed into the Motion Profiling algorithm, making it ready to be followed by the robot.

**PIDVA Trajectory Following:** Once a trajectory is generated, the robot needs to be able to accurately follow that trajectory. This is done using a PIDVA follower. The trajectory gives the robot target velocities at all points of the movement, so those values can be used as the base robot velocities. However, the robot may be at a different velocity than intended, so that needs to be corrected in addition. A Proportional-Integral-Derivative control loop which corrects for the current error, change in error, and sum of all errors is used, along with a Velocity and Acceleration feedforward system. This PIDVA follower allows for the robot to follow trajectories of large complexities accurately.

**Open CV Signal Sleeve Detector:** When approaching the autonomous period, our foremost goal was to detect the signal zone using a sleeve. We use computer vision with OpenCV running on a Logitech C270 webcam to get a stream of images of the sleeve. The sleeve consists of AprilTags, which are commonly used reference images in many industries. The detector determines which AprilTag is shown, allowing the robot to navigate to the right zone.

**Sigmoid Linear Slide Controller:** In order to optimize the speed of the linear slide, we created a sigmoid-based linear slide controller centered at the slide’s target point. We have tuned this controller to quickly raise and lower the slide without damaging the structure or creating oscillations.

**Driver controlled enhancements:**

**Cone Transfer State Machine:** The transfer of cones from the intake arm to the outtake claw can be extremely difficult and tedious for drivers to manually control, so this process is completely automated. Using a finite state machine, the transfer process is done in stages, which include raising the arm, retracting the linear slide, closing the outtake claw, and opening the intake claw. A finite state machine automatically transitions between these stages, allowing the drivers to focus on other actions while the robot picks up a cone.

**Automatic Turret Aiming:** Our turret is automatically controlled, allowing for quicker scoring in autonomous and TeleOp. We use an odometry-based system which calculates the angle from the turret to the nearest medium or high junction and spins the turret to aim towards that pole. Once the turret is aiming in the general direction of the junction, the control switches to the webcam. The webcam uses a custom OpenCV pipeline that isolates junctions using a HSV mask. This allows it to determine the angular error, which it uses alongside a PD control loop to fine-tune the turret’s position.

**Automatic Cone Leveling:** Our double-jointed arm allows us to intake cones at all heights. This can be achieved by creating target servo positions for each possible height. However manual creation of servo position for each height and tuning the values become a slow process. Hence we have developed an automatic cone leveling system which rotates the arm joint based on the arm’s angular position, making sure that the claw stays level at all times.

**Field Relative Movement:** We use Field Relative Movement, which moves the robot relative to the field’s axes, rather than its own axes. This removes the necessity to think about the robot’s angle while driving and allows the robot to move in non-linear path, increasing the efficiency of the robot. This movement is enabled by the IMU’s angle measurements.

**Preset Linear Slide Positions:** Rather than forcing the drivers to manually raise the outtake linear slide to the desired height for scoring on the high, medium, and low junctions, we have preset slide positions for those heights. This reduces driver error while also speeding up cycle times. A similar process is done with the intake slides, with preset values for max and half extensions.

**Restricted Hardware Control:** There are times where moving a specific part of the robot could damage or impair the function of the robot. For example, raising the outtake slide while the intake arm is dropped or dropping the intake arm while the outtake slide is raised. To prevent these events from happening, there are restrictions on the drivers that limit control of certain hardware during different periods of the game.

**Engineering portfolio references:** Pages 6 to 8 on our Engineering Portfolio further discuss the key features of our Software.A picture containing text, clipart

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**Autonomous program diagrams:**

Timeline

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