Conquering Tronassic Park: Jurassic Jokers' Final Prototype

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***Abstract*—Mobile robotics competitions have been a valuable arena to improve the technical skills of budding roboticists for decades. In this paper, we present the Jurassic Joker, a wheeled mobile robot designed for Tronassic Park. The robot has a 2-degree-of-freedom manipulator, with a claw end-effector to grab the Ken doll, and a parallel-linkage-based bucket mechanism to retrieve and deposit the dinosaurs.**

***Index Terms*—Mobile Robot, Tronassic Park, Robotic Manipulator, Drivetrain**

I. Introduction

One of the most fundamental problems in the field of mobile robotics is the ability to manipulate a target object. To be effective in Tronassic Park, the Jurassic Joker not only needs to retrieve and deposit several dinosaurs from varying elevations but must also have enough power to lift Ken from the pit. Provided that these are fundamental problems, the group took inspiration from industry. Namely, ClearPath's Husky robot (Figure 1a [1]) for its agility, ruggedness, and modularity. The base ideated, the group gleaned from crane and snow plough attachments installed on trucks to retrieve Ken and deposit the dinosaurs (Figure 1b [3]).

(a) ClearPath's Husky UGV.

(b) Tow truck with a snow plough attachment.

Fig. 1: Prior art that inspired the design of the Jurassic Joker.

As a result, the Jurassic Joker strategy was intentionally modular, with a bucket module optimized for scooping the dinosaurs, and a claw manipulator for Ken. Invertible controls were implemented to allow for intuitive control of the robot when alternating tasks. Finally, the Jurassic Joker implemented line following to maximize reliability in autonomous mode and time spent in the manual mode zone.

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The group anticipated the design to be able to line follow, collect at least one load of three dinosaurs, and retrieve Ken for a score of 13 points within the time constraint. Per Figure 2, the devised strategy consists of five stages:

1) Line follow autonomous mode in less than 15 seconds, exit with the bucket facing forwards.
2) Collect a load of three dinosaurs, and deposit in the crate.
3) Invert controls and lift Ken from the pit
4) Place Ken on the helipad
5) Invert controls; collect and deposit another load of three dinosaurs (if time permits)

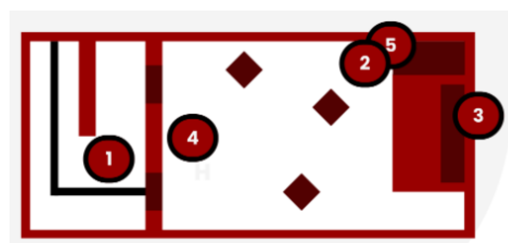


Fig. 2: Gameboard strategy.

In this paper, we discuss each module of the Jurassic Joker, its performance, and key areas of improvement.

II. Methods

As shown in Figure 5, the Jurassic Joker is comprised of four modules: the chassis, the bucket, the manipulator, and the drivetrain. Addionally, the control methodology is presented.

The overall dimensions for the assembly can be seen as Figure 4. The benefit of such a modular design each module is optimized for its specific task, and no compromise for either component is necessary.

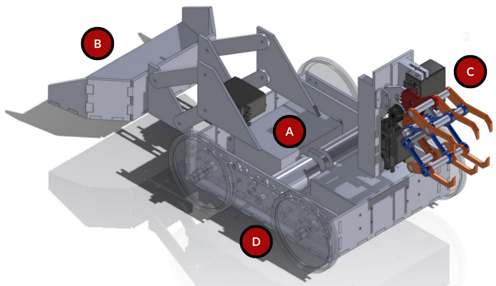


Fig. 3: Assembly with relevant modules emphasized.

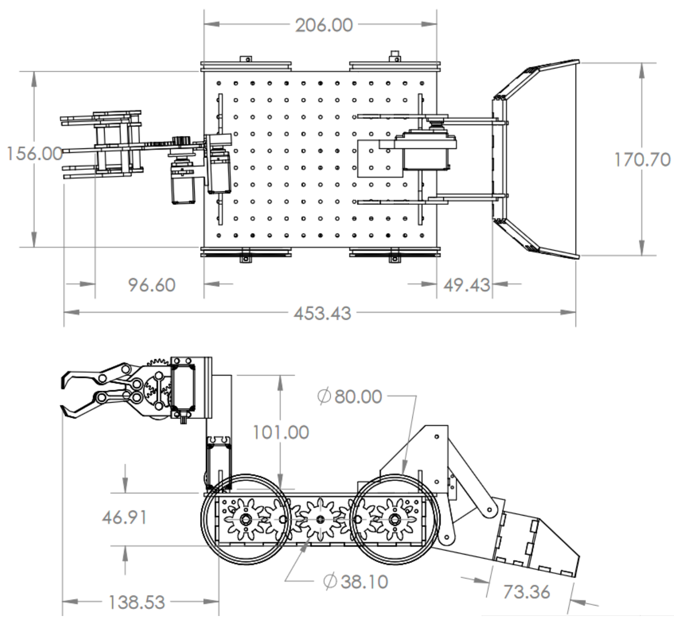
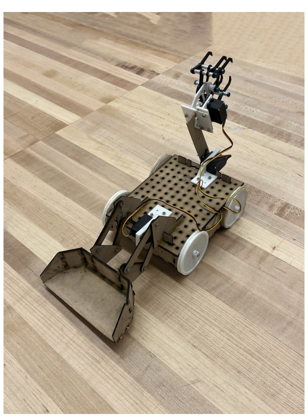
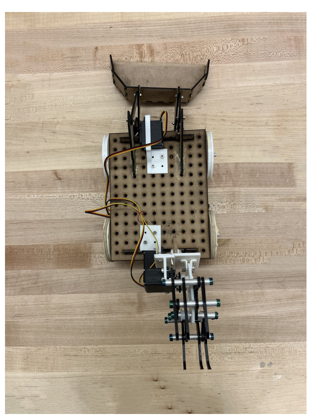


Fig. 4: Overall dimensions of the Jurassic Joker.



(a) Isometric view.



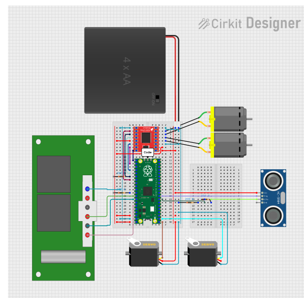
(b) Top view.

Fig. 5: The Jurassic Joker Final Prototype.

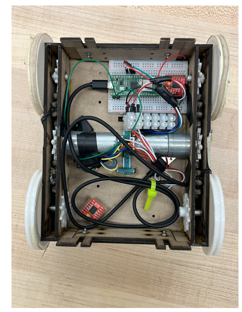
A. Chassis

The Jurassic Joker has a symmetric body shape, nominally with a body dimensions of 206x156x47 mm. It's structure incorporates a perforated top panel, enhancing modularity and ease of assembly. Additionally, the double side walls allow for room for the four-wheel-drive (4WD) drivetrain, and stepper motor mounting.

1) Electronics: All of the electronics are housed under the perforated top panel, shown below as Figure 6a. The Jurassic Joker is powered with a 4xAA battery pack, and computation is done with the onboard Raspberry Pi Pico. The design implements one sensor and five actuators - the line following sensor, two 6V DC 10kg-cm stepper motors, and three HS-422 servo motors.



(a) Electrical schematic; made in Cirkit Designer



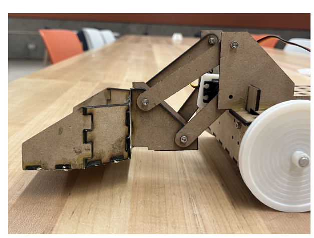
(b) Top view of the electronic assembly.

Fig. 6: Electronic design of the Jurassic Joker.

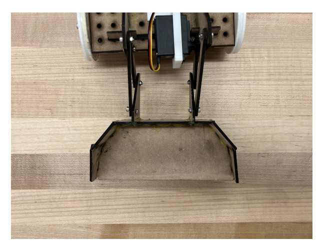
2) Materials: In all, 2.3 in^3 of PLA filament were used in the construction (constituting the claw, line following sensor mount, the wheels, and the gears). By mass, it is estimated that 85% of the structural features of the Jurassic Joker are constructed from MDF board.

B. Bucket Mechanism

Per Figure 7, the bucket mechanism has capacity for three dinosaurs per load. It is attached via a near-parallel linkage mechanism driven by a servo motor. This design mechanically dumps at maximum extension. The bucket has a profile of 74x170x20 mm.



(a) Side view.



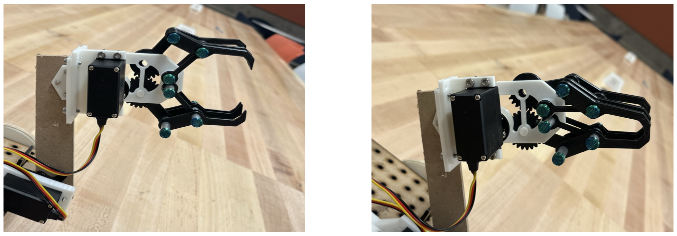
(b) Top view.

Fig. 7: Side and top view of the bucket mechanism.

C. Manipulator

The Manipulator has two-degrees-of-freedom, a revolute joint actuated by a servo at the front of the chassis, and a double-actuated claw.

The claw, shown below as Figure 8, is actuated by a servo. The servo rotates a crank that opens/closes the claw via parallel linkages. Additionally, the actuated gear meshes with the other side of the claw to actuate both sides simultaneously. A GRABCAD model [2] was found and modified to fit the diameter of the provided metal rod at the joints, as well as introducing parallel claw parts to secure Ken at three points of contact instead of one.



(a) Retracted state. (b) Extended state.

Fig. 8: Functionality of the end effector.

D. Drivetrain

As invertible control was a design goal, it was imperative that the transmission system permitted for intuitive control in both directions. For example, if a two wheel drive with a caster-wheel were used, the control system would be intuitive in the forward direction, but would have a very ssmall turning radius in iverted operation. Additionally, it was deemed imperative due to the uneven terrain and uneven loading of Ken, that the force was distributed across all four wheels to minimize the probability of immobilization.

To implement 4WD with only two DC motors, a gear train was installed along either side of the Jurassic Joker to translate torque evenly across all four wheels, pictured below in Figure 9.

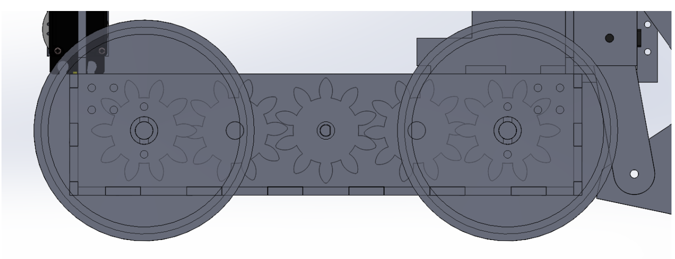


Fig. 9: Screenshot of the 4WD transmission.

E. Control Algorithms

There were two control methodologies implemented on the robot; one each for autonomous line following and for manual mode, the flowchart describing the total, simplified control algorithm implementation can be seen in Figure 10

1) Autonomous Mode: Line following was implemented based on the reading of all three sensors from the line following module, shown mounted to the base of the Jurassic Joker in Figure 11. If the middle sensor reads BLACK, that indicates that the centre of the robot is directly over the intended path, therefore the robot should always drive forwards

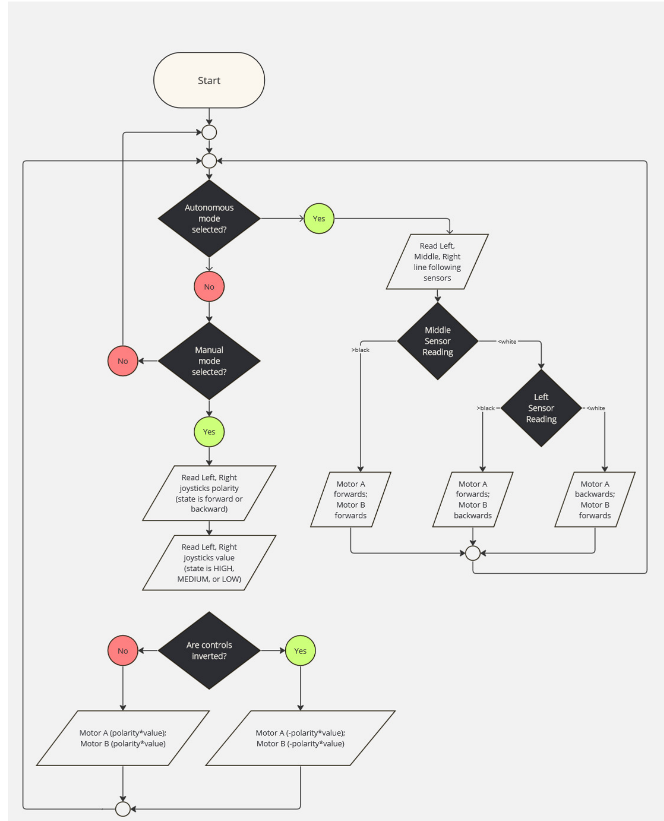
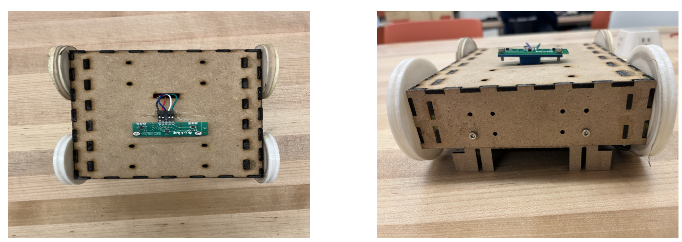


Fig. 10: Simplified control flowchart; made with Miro

(special cases of intersections are ignored). If the middle sensor reads WHITE, the robot should turn towards the other sensor on BLACK.



(a) Top view. (b) Front view.

Fig. 11: Mounting of the DFRobot line following sensor.

2) Manual Mode: Each side of the Jurassic Joker was controlled independantly with the two joysticks on the Logitech controller. Two values were used to determine the command: polarity and value. If the joystick was below normal, the polarity is deemed negative, and vice versa. The value field is categorized as HIGH, MEDIUM, or LOW, and the analog command is mapped to three equidistant PWM commands to the DC motors. If the 'A' button is pressed, the polarity is inversed, but the value remains the same.

III. RESULTS

Ultimately, the Jurassic Joker progressed to the third round of the Tronassic Park competition. However, the performance was poorer than expected for all three mechanical modules.

A. Controls Performance

1) Autonomous Mode: In testing rounds and the all rounds of the competition, the Jurassic Joker successfully completed the line following portion of the competition in under 15s.

2) Manual Mode: It was observed that the controls were responsive on smooth surfaces, such as the autonomous mode board, tables, and the floor. However on the game board, there was not enough torque to pivot as a result of the 4WD.

In the transition from autonomous to manual mode, the Jurassic Joker exhibited unexpected behaviour. Upon impact with the door, the robot moved forward continuously, and had to be reset to restore control. Interestingly, control of the bucket and the manipulator was never lost.

B. Bucket Performance

Although steering was compromised, the bucket mechanism was successfully able to load and unload three dinosaurs at a time on smooth surfaces, and in straight line paths to the bucket.

C. Manipulator Performance

In testing, the end effector was able to securely enclose around Ken, and the triplicate claw design was effectively in ensuring balance. The arm link however, did not have enough torque to lift Ken from the pit. Further modifications to supplement the upward link torque with elastic bands were marginally successful. Ultimately, the manipulator was able to retrieve Ken approximately one in every five attempts.

IV. DISCUSSION

As it pertains to the initial goal of consistently scoring 13 points by line following (4), depositing one load of dinosaurs (3), and retrieving Ken (6), the Jurassic Joker was not successful. As mentioned previously, the principal shortcoming of the design was the steering in the manual mode section, as well as the unexpected behaviour at the transition between zones. To overcome the controls problem, the group suggests augmenting the gear ratio in the drive train to increase the torque to the wheels. Similarly, augmenting the gear ratio with transmission element for the lifting action of the manipulator could supply enough torque to retrieve Ken. As for the unexpected behaviour, the group posits that the load on the battery pack is high while actuating the DC motors and the servos. Upon impact, the DC motors are active but the wheels are not spinning, resulting in a spike in current flowing in the opposite direction through the motor driver, into the microcontroller. It is possible that this surge could reset parts of volatile memory, altering the values of some variables. It is not clear at this time whether this theory is the cause of the unexpected behaviour.

AUTHOR CONTRIBUTIONS

Anthony Beca: Conceptualization, Methodology, Software, Validation, Investigation, Writing – Original Draft, Writing – Review & Editing, Visualization, Project Administration

Luke Parna-Gile: Conceptualization, Methodology, Software, Validation, Investigation, Writing – Review & Editing, Visualization, Supervision

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