RoboCup Rescue 2023 Team Description Paper

BSM Robotics

Charles Nepomuceno, Dr. Matt Miller

Info

Team Name:	BSM Robotics
Team Institution:	Benilde-St. Margaret's
Team Country:	United States
Team Leader:	Charles Nepomuceno
Team URL:	www.bsmrobotics.com

Qualification Videos:

MAN2	https://youtu.be/tb5Oiup6c8k
MOB1	https://youtu.be/nM_0pvFVYfU
MOB3	https://youtu.be/cOOZPK_eUI8
DEX	https://youtu.be/4zXAjG_B768

***Abstract* – BSM Robotics first appeared at RoboCup rescue in 2009 and has since retained its title as the only high school team to have participated in the competition. With over a decade of experience developing search and rescue robots, BSM believes many models have a high price point and knowledge threshold that make them impractical for mass-market distribution and difficult to operate without extensive training. Accordingly, BSM Robotics is dedicated to creating cost-effective and highly functional robots that can be operated with minimal training. This design philosophy differentiates our robots from the competition by presenting an economical and approachable alternative to existing designs.**

***Index Terms* – RoboCup Rescue, Team Description Paper**

I. INTRODUCTION

The 2023 BSM Robotics rescue robot is a complete redesign from the team's 2022 entry. Hindered by major design flaws, last year's Rocker Bogie was significantly limited in maneuverability and durability which diminished navigational performance. Similarly to last year, this year's robot has been designed to prioritize development of a robust mobility base and arm towards the goal of a competitively successful robot that is well-suited to future optimization. In contrast to previous years, however, this year's robot features an emphasis on adapting proven techniques (most notably, tread and flipper design) to BSM's design philosophy.

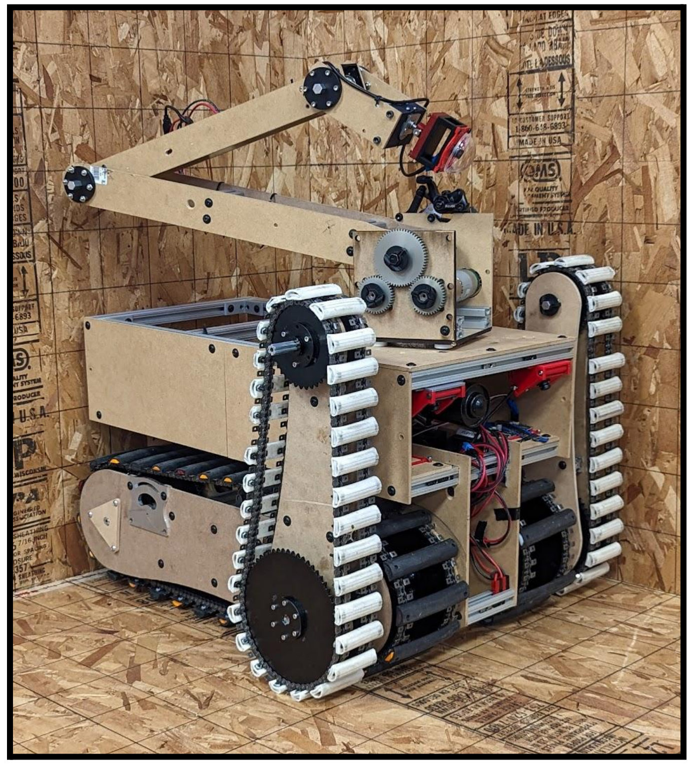

Fig. 1 BSM Robotics' unofficial robot portrait. As of 2/2/2023, the robot lacks rear flippers, a grasper, and is constructed using prototype materials.

This year's robot incorporates two significant adjustments to BSM's technical paradigm. The first change is motor continuity. Using the same type of motor across subsystems improves efficiency by simplifying programming and mount construction. This is liable to change depending on evolving power and mounting demands but, regardless, provides insight into the version of this year's robot seen in qualification videos. The second change is material diversification. Recent entries have relied heavily on 80/20 aluminum extrusions and CNC'd ⅛ in. aluminum sheets. Though the current version seen in qualification videos is constructed primarily out of 80/20 beams and medium density fiberboard plates, we ultimately intend to fabricate treads from aluminum sheets and the arm from polycarbonate sheets. 3-D printed parts will also be used in various non-structural capacities.

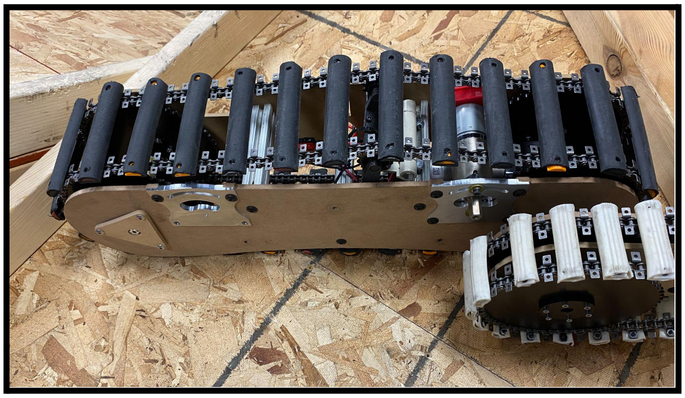

Fig. 2 Prototype tread modules are fabricated out of MDF to accommodate rapid optimization. Vulnerable linkage areas are reinforced as needed.

The robot's tread and flipper combination balances stability, traction, and maneuverability to provide navigational capabilities. In previous years, BSM has chosen not to pursue treaded designs due to concerns about design complexity. This year's model assuages these concerns. It features a reliable, powerful, and intuitive design conducive to consistent application and rapid optimization. This design offers immediate improvement over Rocker Bogie in overall performance.

Furthermore, this year's arm features significant improvements from last year. It is more powerful and better proportioned to balance weight limitations and desired adjustability. We expect the current model to perform well, stow efficiently, and minimize residual impacts to mobility.

II. SYSTEM DESCRIPTION

A. Hardware

Locomotion: The robot's drivetrain utilizes a basic tread and flipper design to maximize maneuverability and traction on rough terrain. It consists of two parallel treads with two adjustable flippers per side. Treads and flippers use the same type of motor with different gear ratios to accommodate variable demands. (Note: In qualification videos, the robot only has two flippers. On the side opposite flippers, two omni-directional wheels are mounted between treads to improve turning capabilities.)

The current tread design is a combination of a CNC'd acrylic/3-D printed internal structure surrounded by a rubber sleeve. One material will be used for both sides after drive performance has been evaluated. Due to the nature of a chain-based system, tensioners are used to reduce derailment throughout natural wear. Currently, drive performance is hindered by construction quality as MDF panels frequently fail under load. Side panels will be constructed out of aluminum plates to eliminate this issue.

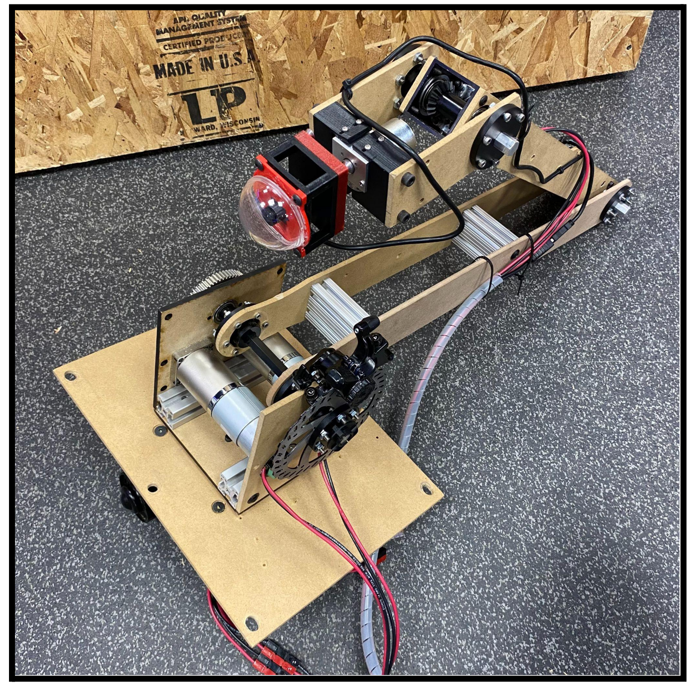

Fig. 3 The current arm module uses variable gear reductions to maintain motor continuity. This streamlines experimentation and part replacement.

Chassis: The robot's mobility base is modular: each tread can be easily detached from the central chassis to facilitate efficient repair. This provides significant advantages over other systems as it allows us to incrementalize modification, changing one subsystem independently of the whole system.

Arm: This year's arm was designed with emphasis on ease of use and overall functionality. Four of five degrees of freedom throughout the arm are manipulated by the same type of motor with different gear ratios. This means many parts and mounting patterns are interchangeable between joints. The prototype in our qualification videos has a maximum reach of three feet from the front face of the chassis. A bicycle brake system (perpetually activated caliper and rotor) assists in static locking and reduces motor drift in the shoulder joint. The current prototype does not include a manipulator per current testing requirements but will ultimately include one. Notably, the shoulder joint is a gearbox utilizing two PG516 Gear Motors and three 50 tooth gears. By using two motors, lifting capacity is nearly doubled.

Electronics: The robot's current electrical setup is similar to last year's Rocker Bogie. Each subsystem features its own power loop running on a single 20V-5AH DeWalt lithium ion battery. This solution is light, efficient, and allows for better failsafe protocols. Robots with a single power source are vulnerable to complete shutdown if one component fails. By using multiple batteries, we expect our robot to function even if one or more subsystems are disabled.

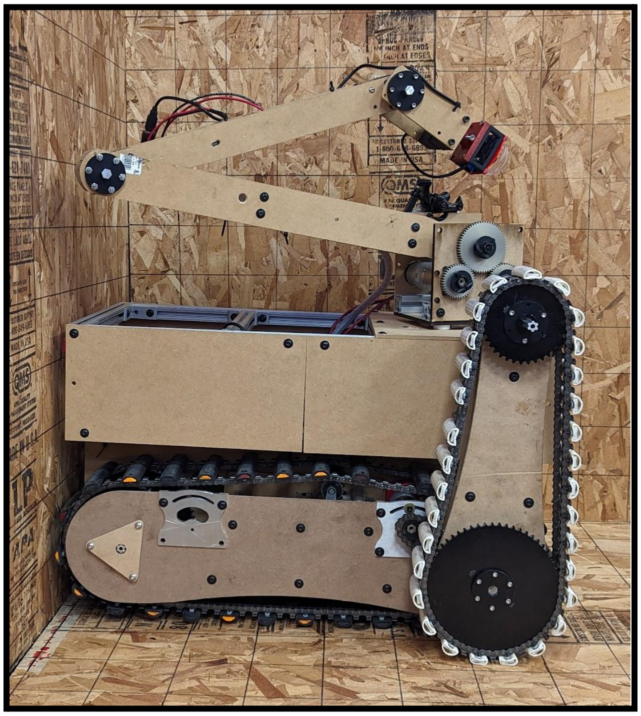

Fig. 4 Side view of the robot against a 10cm grid.

B. Software

Like last year, tele-operative navigation is managed by visual data streamed through a website-based Raspberry Pi system. The system (a locally hosted webpage through a Flask server) is compatible with a standard wifi network and Ras Pi cameras which will provide the operator with edge, horizon, and obstacle detection data. Notably, this system includes a Python based in-house motor library to streamline programming and alteration. Functionally, this means the operator will see camera data on the same webpage they control from. Once the system is powered on, the robot can be controlled remotely by any device that can interface with the bluetooth Playstation 4 controller and access the same network as the Raspberry Pis.

C. Communication

We plan to use a wireless access point on the robot that connects to a wifi router at the operator station. Specifics are in progress.

D. Human-Robot Interface

Operating on a Flask-based webpage centralizes key robot functions and creates a more convenient user interface. Minimal training is required because Playstation 4 controls are intuitive to most users. This marks an improvement from last year: WASD keyboard controls were easy to program but more difficult to achieve desired functionality. As seen in BSM's qualification videos, operators can effectively control the robot even when using it for the first or second time.

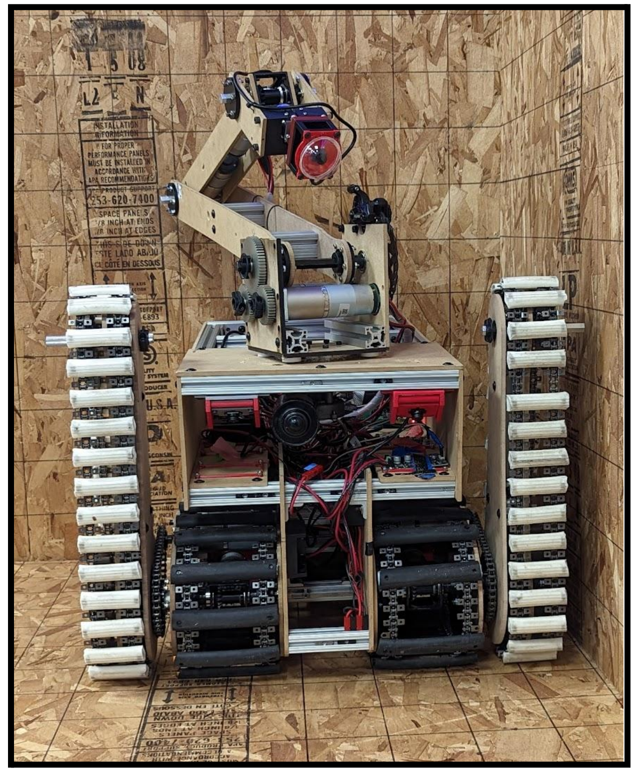

Fig. 5 Front view of the robot against a 10cm grid.

III. APPLICATION

A. Set-up and Break-down

Each tread and flipper module is removable and the arm system is secured to a removable top plate. All motors in these subsystems connect to motor controllers through quick disconnect Anderson powerpole connectors. Like last year, operator start-up is as simple as opening a laptop and connecting to the network. Specifics are in progress but our approach is minimalistic to an extreme, expecting to only need a computer, WiFi router, and connection to the Raspberry Pis.

B. Mission Strategy

As previously stated, BSM Robotics is committed to developing a cost effective and highly functional mobility base that can be operated with minimal training. This year, we have prioritized arm optimization and development of a new mobility base. We plan to focus on maneuverability and mobility tasks with a secondary focus on dexterity.

Research and development surrounding advanced mapping and sensing capabilities begins to move beyond our current interests and capabilities. Our philosophy is that a rescue robot should be accessible to all users by relying on simple-to-program and easy-to-use controls. Advanced mapping and sensing capabilities complicate operation and increase overall price beyond what we think is justified by our strategy.

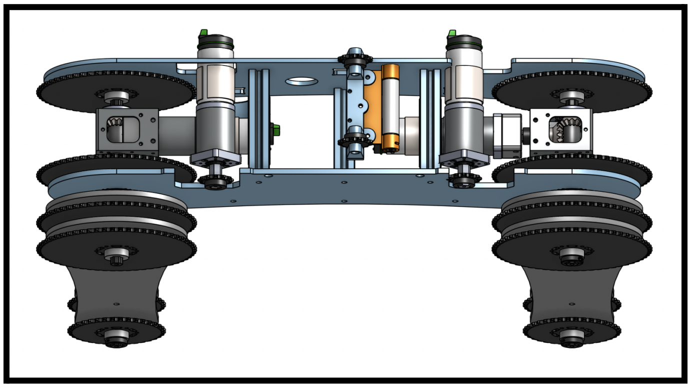

Fig. 6 CAD model of tread and flipper assembly. The assembly does not reflect connection between flipper motors and chassis or chain systems.

C. Experiments

We continue to take advantage of our in-house RoboCup Rescue test arena. Students are encouraged to test design concepts and evaluate ease of use and control accuracy of robots and data systems. The lab provides multiple computers and Raspberry Pis for testing code. Students can also create smaller robots to test new concepts. While we do not have standardized test methods at this time, we aim to isolate mobility and maneuverability tasks from dexterity tasks to facilitate independent optimization.

Initial trials of MAN2, MOB1, and MOB3 were complicated by lack of traction and construction failure. Omni-directional wheels mounted to the rear supplement otherwise poor turning (made worse by the lack of rear flippers) but significantly reduced traction during the K-Rails challenge. Throughout all tests, MDF panels on treads and flippers failed in the same location due to stress on bearings. When tread plates are fabricated from aluminum and rear flippers are installed, we believe performance will drastically improve.

D. Application in the Field

Search and rescue is a versatile field that requires constant innovation in a variety of specific subfields. However, even with this in mind, BSM Robotics believes creating a general mobility base that can be adapted to a wide range of scenarios is equally important. This is what we hope to accomplish. By creating a standardized chassis, robust treads, and powerful arm – all at a low cost – we have the opportunity to test multiple designs, understand their performance in crisis situations, and provide a fully functional platform that balances performance with affordability.

No design is perfect. Our robot has its fair share of flaws, and it is important to recognize that these may hinder performance in the field. For example, mapping capabilities are severely limited because we have chosen to prioritize other areas.

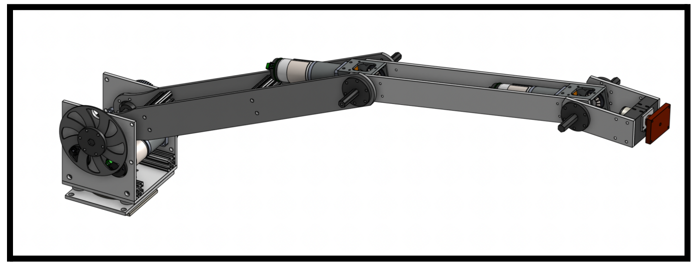

Fig. 7 CAD model of arm assembly near maximum extension. The assembly does not reflect our current turret system, brake caliper, or grasper.

Issues also exist within assemblies we focused on. The robot's treads are vulnerable to dealignment or failure under load. The arm's large profile might pose an issue to overall stability and maneuverability.

The largest roadblock to real-life application is likely mapping and scale. In the future, we hope to explore advanced mapping tools that can provide a better image of crisis areas. Since some rescue situations require robots to negotiate tight spaces, we would like to explore a more compact version by scaling down chassis and tread assemblies. Scaling will likely be accomplished by competition time while mapping would be a long term project.

In spite of this, BSM Robotics is still extremely pleased with what we have developed. This year's robot marks the most advanced prototype constructed by this point in the year and has major potential for optimization in future years.

IV. CONCLUSION

This year, BSM Robotics has pursued a complete redesign. The team has implemented takeaways from previous years and taken inspiration from competitively successful robots to refine our current design. This approach provides visible reference points and tangible goals to work towards.

This robot is the most successful our program has seen at this point in our trials. Its overall design is applicable to every challenge we have tested, and in light of continued improvements in software, mechanics, and construction, we expect this year's robot to be the best we have brought to RoboCup Rescue thus far. We are excited to compete this year and show the competition what we have spent the past six months designing, constructing, and refining.

ACKNOWLEDGMENT

The BSM Robotics Team would like to thank Benilde-St. Margaret's and our sponsors for funding this program. We would also like to thank our advisors Mr. Charles Nepomuceno and Dr. Matt Miller who keep the entire program running smoothly. Finally, we would like to recognize every student who has contributed to BSM Robotics this year.

APPENDIX A
TEAM MEMBERS AND THEIR CONTRIBUTIONS

Subsystem Leads:

Evan Nowlin	Mechanical Design: Treads and Chassis
Kent Gerads	Mechanical Design: Arm
Val Coppo	Software: Motor-User Interface
Tommy Medina	Software: Sensors and Visualization

BSM Graduating Classes of 2023 and 2024:
Robot Design, Fabrication, Assembly, and Programming

APPENDIX B
CAD DRAWINGS

Figures 6 and 7 display current tread and arm assemblies, respectively. A complete CAD assembly including absent components and range of motion is in progress.

APPENDIX C
LISTS

Hardware components are shown in Table I; Manipulation system is shown in Table II; Software is shown in Table III.

TABLE I
HARDWARE COMPONENTS LIST

Subsystem	Item	Qty	Est. Cost
Arm/Claw	PG516 Gear Motor PG188 Gear Motor CQRobot 270:1 Gear Motor Assorted 20DP Gears Armabot Right Angle Drive Trossen Robotics Roller Bearing Misc. Stock Material Misc. Hardware	4 1 2 3 2 1 Varies Varies	375 USD 95 USD 60 USD 60 USD 120 USD 25 USD 50 USD 20 USD
Drivetrain	PG516 Gear Motor PG188 Gear Motor Misc. Chains Misc. Sprockets Misc. Stock Material	4 4 Varies Varies Varies	375 USD 375 USD 25 USD 300 USD 50 USD
Sensors/ Electronics	Cytron Rev 2.0 Motor Controller Raspberry Pi 3 Raspberry Pi 4 Misc. Wires 5V Battery 20V Battery 8mm Lens Camera H.264 Pimoroni IO Expander Battery Mounts	6 1 1 Varies 2 5 4 2 6	140 USD 35 USD 45 USD ?? USD 50 USD 140 USD 160 USD 9 USD 100 USD
Robot Structure	8020 Extruded Aluminum Misc. Stock Material	15ft Varies	40 USD 40 USD
Operator Controls	Macbook Computer PS4 Controller	1 1	2000 USD 60 USD

TABLE II
MANIPULATION SYSTEM LIST

Attribute	Value
Name	na
Locomotion	Treads
System Weight	52kg
Weight including transportation case	100kg
Transportation size	na
Typical operation size	1.05m x 0.6m x 0.7m
Unpack and assembly time	na
Startup time (off to full operation)	na
Power consumption (idle/typical/max)	na
Battery endurance (idle/normal/heavy load)	na
Maximum speed (flat/outdoor/rubble pile)	na
Payload (typical, maximum)	na
Arm: maximum operation height	100 cm from top; 145cm from floor
Arm: payload at full extend	na
Support: set of battery chargers total weight	na
Support: set of battery chargers power	na
Support: charge time batteries	1 hr
Support: additional set of batteries	na
Any other interesting attributes?	na
Cost	na

TABLE III
SOFTWARE LIST

Name	Version	License	Usage
Flask	2.2.2	BSD	Hosts interface
jQuery	3.2.1	MIT	Sends data between server webpage
Pimoroni IO-expander library	0.0.3	MIT	Library which facilities Pimoroni GPIO-expander board communication
Open CV	4.7.0	OSI	Facilitates the sending of camera data