Adapting Industrial Technology for Botball Robotics

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***Abstract*—In this paper, everyday technology helps build better robots for Botball. Ideas from common objects and vehicles improve the robot's structure and guide the selection of appropriate parts. The goal of this paper is to evaluate whether industrial concepts, specifically AGV-inspired line-following and pick-and-place gripping systems can improve the reliability of a Botball robot, measured by success rate in autonomous cone collection. The industrial ideas are not copied directly, but adapted to fit the robot and make it more reliable in the competition. The results show that a motor power setting of 35% achieves a 100% success rate, demonstrating that adapting proven industrial concepts significantly improves consistency.**

I. INTRODUCTION

The field of robotics is evolving rapidly, making it increasingly challenging to identify new sources of inspiration for developing more advanced robotic systems. Building a robot is a difficult task in international competitions [7] such as Botball, especially for inexperienced teams [6]. To make robot construction more accessible to beginners, existing industrial machines are used as references for the design of individual robot components.

This paper analyzes how technologies from modern logistics and automation can be applied to the design and construction of robots. A central challenge in Botball is the precise approach and collection of specific objects, such as cones. In industrial environments, this task is often handled by **Automated Guided Vehicles (AGVs)** [3] and robotic picking systems.

One effective way to navigate these environments is through optical path guidance. Modern AGVs often use infrared sensor arrays to follow predefined tracks on warehouse floors. To adapt this for a Botball robot, a triple-sensor line-following system is implemented [2]. Instead of complex vision systems [10], high-speed infrared reflectance sensors detect the contrast between the game table and navigation lines. The software processes these values in real-time to calculate a **Correction Variable**, allowing the robot to adjust its motor power dynamically and stay centered even at higher velocities.

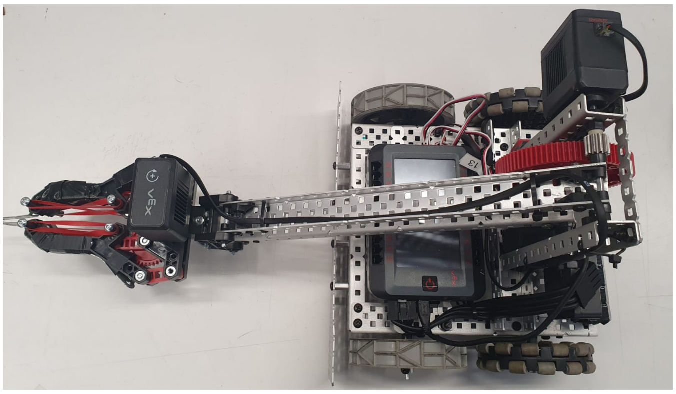
Fig. 1. A picture of the robot, which executes the experiment.

Once the robot reaches its target, a mechanical gripping system is required to interact with the environment. Inspired by industrial robotic arms used in ”pick-and-place” applications [9], the team developed a motorized claw. This system, combined with the precise line-following logic, helps the robot to reach and pick up cones with high reliability.

Using these established industrial concepts reduces the time needed to develop a hardware design fitting the task. This shows how professional automation technology, similar to systems used in modern logistics, can be adapted to make a Botball robot more efficient and easier to build for beginners.

II. IMPLEMENTING THE CLAW

The construction of the robot is guided by mechanisms commonly found in automated logistics, with a particular focus on **robotic picking arms**. The claw is designed to approach and secure objects efficiently, making them a suitable reference for a reliable **claw system**. In this project, industrial pick-and-place units serve as the primary inspiration for the robot's gripper. Its structural layout provides a stable foundation for holding **cones** Figure 2 during the match.

The intake mechanism is modeled after the lifting process used in factory automation, such as an amazon warehouse, where a gripper secures the target to make sure it doesn't slip out. This concept is adapted into a compact mechanism that fits the size constraints of the competition field while maintaining consistent performance. Furthermore, the mechanical geometry of the claw offers insight into how objects can be prevented from falling out during rapid movement. This principle is applied to the robot by incorporating high-friction surfaces that secure the cones. As you can see here: Figure 1

Fig. 2. One of the two cones (gamepiece) that will be used for the experiment. (both of them are the same)

A. *Design Integration Challenge*

The **motorized claw mechanism** [5] has no direct equivalent in standard excavator technology. To address this, the design is divided into two functional zones: a navigation module inspired by AGV engineering, and a front module optimized for grabbing tasks.

The **front claw** secures cones and moves them for transport. This process ensures that the objects reach the target zone without obstruction. This hybrid approach maintains thematic consistency while prioritizing performance on the game table. The combination of a real-world inspired drivetrain and a competition-optimized gripper results in a balanced design.

III. METHODS

The experiments are conducted using the following methods. The average time will measure the time it takes on average to conduct a part of following experiments, the times that succeeded and failed, as well as the average success time it takes to carry out the individual experiments. Five runs will be conducted in order to get values. The run is a failure, when the Robot doesn't grab a single cone. The experiment will test different speeds of the robot to figure out the optimal time the robot takes to pick up the cones.

A. *Experimental Setup*

The experiment is going to try to pick up cones (a Botball 2026 Game piece). A picture of it is here: Figure 2
The setup can be seen here: Figure 3

IV. EXPERIMENTAL VALIDATION: VELOCITY VS. POSITIONING ACCURACY

After we found out, that the original design of the robot was flawed, the redesign of the robot to a more compact form, a recalibration of the movement patterns became necessary. The new chassis is approximately 13 cm shorter and 6 cm narrower than the previous version. Although the switch to 5.5W motors reduced the total weight, the handling of momentum changed significantly [8]. This section explains the optimization of speed to ensure the robot hits the fixed cone positions on the game table with 100% reliability.

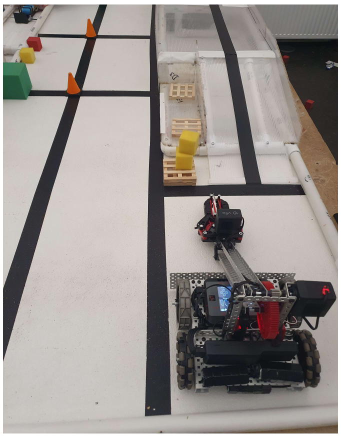

Fig. 3. The setup of the experiment

A. *Measurement Unit: Definition of Motor Ticks*

To obtain exact results, all movement data is measured in ”Ticks”. A Tick represents the smallest digital unit provided by the internal encoders of the VEX V5 Smart Motors [4]. In the specific configuration with 5.5W motors, one full 360-degree rotation of the motor shaft is divided into 900 Ticks [1]. For this setup, a movement of approximately 15 Ticks corresponds to about 5 mm of travel. The term ”Overshoot” is used to describe the distance between the programmed stop point and the actual physical position of the robot due to kinetic energy.

To illustrate the processing of these Ticks and the Correction Variable during the autonomous phase, Algorithm 1 explains the logic of the line-following and stopping sequence.

Algorithm 1 Line-Following Logic and Positioning

```
Require: $TargetTicks \leftarrow$ calculated distance to cone
Require: $BaseSpeed \leftarrow 35\%$
$CurrentTicks \leftarrow 0$
while $CurrentTicks < TargetTicks$ do
    $L, C, R \leftarrow$ read infrared sensors
    $CorrectionVariable \leftarrow (L - R) \times$ Sensitivity
    $MotorLeft \leftarrow BaseSpeed + CorrectionVariable$
    $MotorRight \leftarrow BaseSpeed - CorrectionVariable$
    $CurrentTicks \leftarrow$ get average encoder value
end while
STOP ALL MOTORS (Brake Mode)
$Overshoot \leftarrow$ ActualFinalTicks $- TargetTicks$
```

B. *Testing Parameters and Objectives*

The objective was to determine the maximum velocity the line-follower can handle before the momentum-induced overshoot exceeds the mechanical tolerance of the grabbing mechanism, making the robot not stay on the lines. Three power levels were tested, with five runs per speed to ensure statistical relevance:

- **20% Speed:** Establishment of a high-precision baseline.
- **35% Speed:** Proposed competition speed to balance efficiency and reliability.
- **45% Speed:** A stress test to observe the reaction of the compact chassis to high-speed braking.

C. *Data Collection and Results*

The following table summarizes the performance data. ”Time” represents the average duration to complete the test segment.

TABLE I
IMPACT OF SPEED ON POSITIONING ACCURACY

Driving Mode	**Velocity**	**Time (avg)**	**Overshoot**	**Success Rate**
Slow	20%	20.38s	3 ticks	100%
Normal	**35%**	**17.98s**	**16 ticks**	**100%**
Fast	45%	16.61s	58 ticks	40%

To show the relationship between velocity and positioning error, the data from Table I is visualized in Fig. 4.

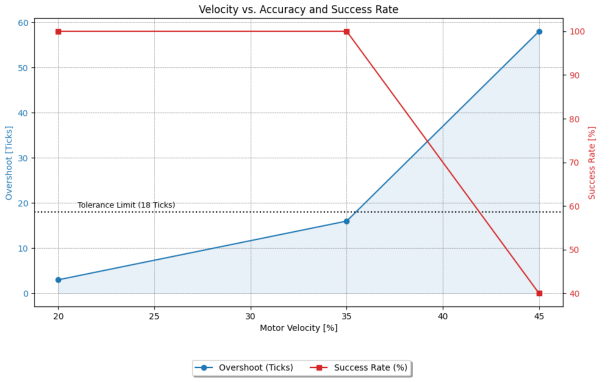

Fig. 4. Impact of velocity on overshoot and success rate

D. *Analysis and Final Strategy Selection*

The results indicate a critical threshold between 35% and 45% speed. At 45%, the overshoot of 58 ticks significantly exceeds the mechanical tolerance of the claw (18 ticks). This resulted in a success rate of only 40%, meaning the robot failed to grab the cone in 60% of the attempts due to high momentum.

In contrast, the 35% speed configuration produced a manageable overshoot of 16 ticks. This falls within the 18-tick safety margin, maintaining about a 100% success rate while saving 2.40 seconds compared to the slow mode. Additionally, the 35% setting was selected because it produces consistent results. At 45% speed, the robot succeeded in some runs but failed in others, making the performance unpredictable. A lower speed ensures that every run behaves the same way, which is more valuable in a competition than occasional high-speed success. Consequently, the 35% velocity setting was selected as the final competition strategy to ensure both speed and absolute reliability.

V. CONCLUSION

The process of building a Botball robot is challenging and can be made easier by analyzing industrial technologies that already exist in the real world. The compact body of the robot, along with the motorized claw, functioned reliably during operation.

It was determined that a 35% motor power setting allows the robot to pick up objects successfully in almost every attempt. This indicates that a reduction in speed significantly improves precision and consistency. Therefore, the prioritization of reliability over high velocity is considered more effective to avoid errors during the match. This project tries to demonstrate that the machines used in everyday industrial logistics, such as AGVs and robotic arms, provides valuable insights for the improvement of Botball robots. Proven mechanical solutions, specifically industrial pick-and-place systems, serve as a strong example of effective object handling and reliability.

VI. ACKNOWLEDGMENT

The authors would like to thank Dr. Michael Stifter and Ing. MSc. Eichberger for helping with this project and giving constructive criticism, which greatly helped improve on our work.

Another thank you goes to Lukas Rennhofer, Thomas Schweiger, Mikail Ülger, Rüzgar Gündüz, Martin Lindner, and Moritz Rottensteiner for giving tips on how to improve the structure of the paper, as well as helping the authors with their grammatical issues, improving the quality of this project.

REFERENCES

[1] VEX Robotics, ”V5 Smart Motor Technical Specifications,” 2024. [Online].
Last accessed date: 10. 04. 2026
https://v5rc-kb.recf.org/hc/en-us/articles/
9636302498711-Recommended-Tools-for-VEX-V5-Robotics-Competition-Teams

[2] M. Sanaatiyan, ”A line follower robot from design to implementation”, ResearchGate, 2010. [Online]
Last accessed date: 10.4.2026
https://www.researchgate.net/publication/224132741_A_line_follower_
robot_from_design_to_implementation_Technical_issues_and_problems

[3] AGVs, ”What is an AGV?”, Qviro, 2023 [Online].
Last accessed date: 10. 04. 2026
https://qviro.com/blog/automated-guided-vehicle/

[4] S. Lee and K. Kim, “Development of Precise Encoder Edge-Based State Estimation for Motors,” *IEEE Transactions on Industrial Electronics*, 2016. [Online]
Last accessed date: 10. 04. 2026
https://ieeexplore.ieee.org/document/7428936

[5] N. S. Selby and H. H. Asada, “Learning of Causal Observable Functions for Excavation Automation,” *IEEE Robotics and Automation Letters*, 2021. [Online].
Last accessed date: 10. 04. 2026
https://ieeexplore.ieee.org/document/9464690

[6] A. Klomp, “The educational robot inspiring students of all ages *TU Delft Open Education*, 2025. [Online]
Last accessed date: 10. 04. 2026
https://www.tudelft.nl/en/stories/articles/the-educational-robot-inspiring-students-of-all-ages

[7] D. J. Silk, R. Schunn, and J. Shoop, “Resources for Robot Competition Success: Assessing Math Use in Grade-School-Level Engineering Design,ResearchGate, 2011. [Online]
Last accessed date: 10. 04. 2026
https://www.researchgate.net/publication/344528608_Resources_for_Robot_Competition_Success_Assessing_Math_Use_in_Grade-School-Level_Engineering_Design

[8] K. Lynch and F. Park, *Modern Robotics: Mechanics, Planning, and Control*. Cambridge University Press, 2017. [Online]
Last accessed date: 10. 04. 2026
https://ieeexplore.ieee.org/document/8897162

[9] N. S. Selby and H. H. Asada, Toward Autonomous Excavation of Fragmented Rock, 2008. [Online]
Last accessed date: 10. 04. 2026
https://www.researchgate.net/publication/3449083_Toward_Autonomous_Excavation_of_Fragmented_Rock_Full-Scale_Experiments

[10] G. Bradski and A. Kaehler, Learning OpenCV: Computer Vision with the OpenCV Library. 2008. [Online]
Last accessed date: 10. 04. 2026
https://ieeexplore.ieee.org/document/5233425