Development of an Omni-Directional Ball Launcher

Capstone Report

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This project report was created on TexStudio editing platform using LaTeX. All the figures were drawn using draw.io online software tool.

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Title:
Development of an Omni-Directional Ball Launcher

Theme:
Enhancing Footballers' Technical Skills.

Project Period:
Fall 2023 - Spring 2024

Project Group:
Sultangali Arzykulov Lab

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Supervisor(s):
Sultangali Arzykulov

Copies: 1

Page Numbers: 15

Date of Completion:
April 26, 2024

Abstract:

To excel in football, a player must enhance both technical and tactical abilities. This improvement is achieved through repeated practice of ball-handling positions. A study introduces a design for a football throwing machine, capable of consistently directing and propelling the ball for thorough educational assessment. The machine features a ball loading canister to accommodate multiple balls, and two polyurethane throwing wheels mounted on a horizontally fixed body. Each wheel's speed can be adjusted independently. Horizontal ball movement is controlled by the difference of speeds at each motor, and vertical ball movement is controlled by the lifter mechanism, while electronic systems manage velocity, direction, trajectory. Speed and direction control operation are controlled with two separate DC motor speed controllers. At this project we used the universal motors which can run from DC and AC power source. However, we using the DC 36V power source with charge controller mounted into the device frame.

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Preface

In the realm of technologies and electronics, the help of invented devices to improve the technical skills of each professional specialists is enormous. This project explores impact of the ball thrower machine to an enhancing of the footballers skills. The project's aim lies in its potential to reshape training methods of footballers. The essence of this work is directed towards applications in both the fields of enhancing the skills of footballers and developing the throwing machine technologies, making it a versatile and valuable technology to achieving the best performances of football players.

I wanted to express my heartfelt gratitude to my supervisor professor Sultangaly Arzykulov, for his unwavering support and guidance throughout the development of this capstone project. His research mentorship has not only improved my research and engineering skills but has also inspired me to pursue academic career. Without his help, I would have never had the opportunity to get acquainted with my topic and would not develop this project to its final form.

Nazarbayev University, April 26, 2024

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Chapter 1

Introduction

Football, also known as soccer, is a team sport involving a spherical ball and played by two teams, each consisting of 11 players. It boasts an extensive global following, with approximately 249 million players across more than 190 countries and territories, making it the most widely played sport worldwide. Matches take place on a rectangular field called a pitch, with a goal situated at each end. The primary objective of the game is to score points by maneuvering the ball past the opposing team's goal line and into their goal [1].

In our nation, there is an undeniable passion for football, and participation rates are high. However, the desired level of success has not yet been achieved. It can be argued that the primary determinant of a football match's quality is the technical prowess of the players. A refined technique involves footballers executing movements efficiently and effectively [2].

For a footballer to possess a refined technique, mastering control over the ball during kicking or passing is essential. This control can be exerted using various body parts like the head, chest, or feet, adapting to different positions on the field. The ability to stop the ball depends on factors such as its speed, height, direction, as well as the player's individual technique and habits [3]. Developing a player's control and dominance over the ball requires repetition, as studies indicate that repeated movements lead to subconscious memorization, resulting in improved performance during matches, both technically and visually. Tests exist to assess a player's technique in football, but some rely on human passing, which introduces variability in the ball's velocity, height, and direction. To ensure consistent training of specific maneuvers, a machine proves more reliable, capable of executing the same action repeatedly once programmed. A ball throwing machine, for instance, enables a player to train independently without relying on another person, offering consistent training opportunities regardless of environmental conditions [4].

There are several sizes of soccer ball depending on the age of the players. For our project we chose first to develop the standard 5 size machine. The size 5 internationally has the circumference between 69 cm and 71 cm [5].

While innovative technological devices may not be widely recognized among sports audiences, some European clubs have embraced them to enhance their performance and achieve better results. These devices are utilized not only for injury recovery but also for overall performance development [6]. The Football Launcher stands out as a prime example of technological advancement in the soccer industry of the 21st century. Invented and designed by Christian Guttler in Berlin, Germany, the Football Launcher is a training system aimed at improving players' first touch with the ball and their instant reactions [7].

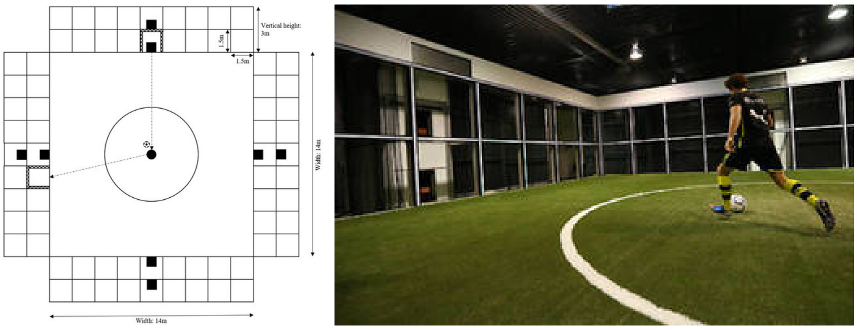


Figure 1.1: Footbonaut

The Footbonaut is engineered as an advanced training apparatus that replicates the dynamic aspects of football gameplay, integrating both physical (such as dribbling, passing, and shooting) and perceptual-cognitive (involving information processing from auditory and visual cues) elements. Its design comprises a 14 × 14 m artificial turf surface provided by Morton Extrusionstechnik GmbH in Absteinach, Germany, enclosed by four walls. These walls are constructed of 72 precisely positioned square panels, including 64 target gates and 8 ball dispenser gates, each measuring 1.5 × 1.5 m. There are two horizontal rows of gates per wall. Each gate is equipped with light barriers around its perimeter and light-emitting diodes to detect and measure the ball's passage through the gates[8].

Chapter 2

Skills and Background

This paper will investigate the construction of a soccer-ball launcher. In the beginning of the project it was planned to design a machine which can be adjustable for several size types of ball. However as we started our project in the second half of the given time we decided first to make workable prototype with one size of balls in particular size 5. Developing the skills of the football players using new technologies can contribute our countries football development hopefully to see them in the world scenes. After finishing this project, we would like to conduct a research on designing the more professional machine which is really can be used in the commercial areas for long term purposes. Therefore I believe this paper will be the foundation for further investigations.

By the end of this project I hope that I will learn many new technical skills such as designing devices, research skills. Now I need to learn more about the basics of dynamics of ball throwing and the technical availability of electronics and construction parts, that is why I need to improve my research skills, and I need to learn in detail the parts which is needed for designing the ball throwing machine in case if we can make a really professional device in mass production which can be used for long term purposes. Below provided one of the devices that already existing as professional training tools.

Figure 2.1: Professional Ball Launcher

Chapter 3

Methodology

The main goal of the paper is to design the ball throwing machine. To design this technical device I need firstly know the some statistic of football game. First we need the ball size 5 as aforementioned. Standard size five ball has the circumference length of from 68 cm to 71 cm and weight between 410 and 450 grams. This ball size is used in the games where the players can be from 15 year old and above [9].

Figure 3.1: Size of soccer balls[10]

The speed of the ball. The highest speed of the ball that ever was kicked in the game is 129 km per hour. However the average speed that balls acquiring in the games is about the 70 km per hour[11].

Ball throwing machine mechanical parts. For our prototype we decided to use available materials in the market. For the parts of main body which will hold the motors, we will use steel angle bars with sizes 30x30x3 and 40x40x3. To interconnect the main body parts where applies less forces we will use lighter mass profile tubes.

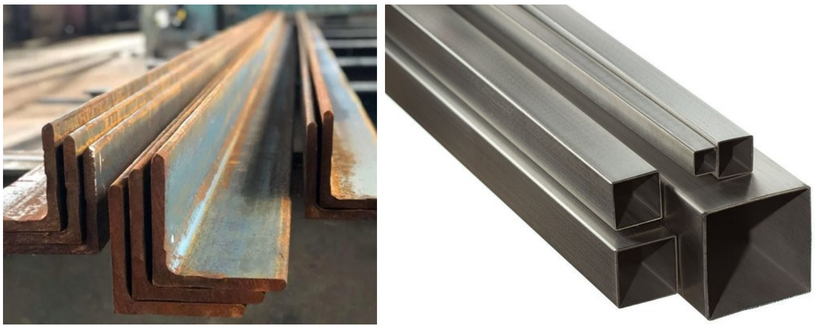


Figure 3.2: Mechanical parts

Electronic parts First we decided to use hoverboard motors. The reason for this is that they hub motors which means they are direct drive where stator and the rotors are the parts of the wheel. The advantage of this motor would the fact that it is easy to mount to the main body without any problems. For instance hub motor ideally balanced against any vibarations that can arise during the high RPM rotations. As aforementioned before we need average speed of 70 km per hour.

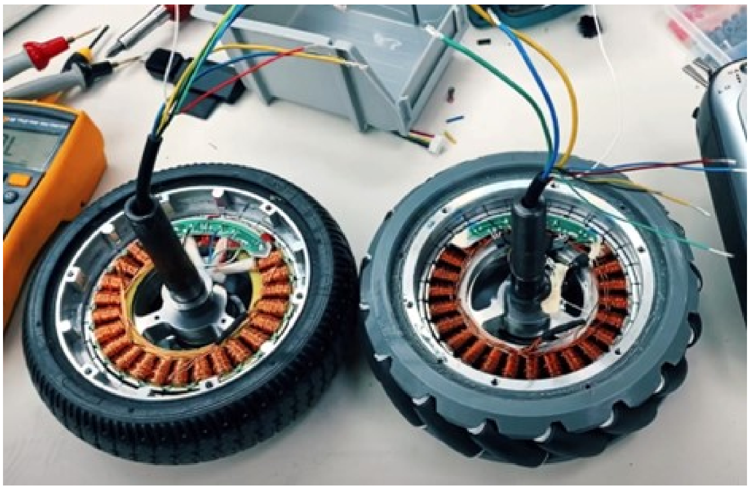


Figure 3.3: Hub motors

The biggest diametr for hoverboard wheels is 10 inches which is 25 in cm. For this size we have to calculate the necessary value of RPM with next formula where N is value of RPM, V is the velocity of the ball, r is the radius of the wheel [12].

$$N = \frac{V}{2*\pi*r} = \frac{70*60}{2*\pi*0.125*3.6} = 1485rpm$$

However this calculated RPM is for ideal conditions where the all the energy of the wheels is transferred to the kinetic energy of the ball without any losses. We can take this value as aproximation for the protype. As seen from Figure 3.3 hub motors are not typical DC motor even if they powered from 36V DC battery. The speed control of hub motors are done with their factory controller which looks like as below.

Figure 3.4: Factory hoverboard hub motor's controller

Unfortunately it turned out that the hub motor from the hoverboard is not appropriate for our project. Because the maximum RPM we could take from that motor was around 700 RPM [14]. As we are run out of time we could not continue to conduct the research on how to increase the maximum RPM of hub motors up to 2000 RPMs. Instead of that motor we found a replacement from industrial devices such as washing machine. Indeed we could use other high RPM DC motors but in the territory of our country there was no available one. We could order from abroad, but again it requires more time than we have for the delivery.

The motor from washing machine is the universal motor which means it can run from either AC or DC power source. Below provide some characteristics of universal motor we chose [15].

To ensure whether the power of this motors are enough to launch the ball with 70 km per hour we need to make next calculation [16].

Radius of the ball, $r = 11cm$
Mass of the ball, $m = 400g$
Wheel radius, $r = 11cm$
Speed of the motor $N = 1485rpm$

The amount of energy to launch the ball

$$K.E_b = \frac{mv^2}{2} = 209j/sec$$

The amount of energy stored in wheel while spinning

Universal Brushed Motor	
RPM range	0-13500 rpm
Power Source Type	AC/DC
Power	300 W

Figure 3.5: Universal motor from wahsing machine

$$E_s = \frac{I\omega^2}{2}$$
$$I = 1.98 * 10^{-3} kg - m^2$$
$$E_s = 80 j/sec$$

Total Power reqiured to launch the wheel which motor should consume is

$$TotalEnergy = K.E_b + E_s = 289W * s$$

As we see our 300W motors is enough powerful to eject the ball with necessary speed.

Power source. For our project, mobility of the device is one of the main criteria. Therefore we chose 10s2p Li-Ion, 36V, 4400mAh battery.

Figure 3.6: Electronic parts

Control of the speed. Next is the speed control device. We used a ordinary voltage regulator which is made special for speed controlling of DC motors. However we took the one which handle up to 60V in case if we need more power and RPMs.

Chapter 4

Results

4.0.1 Design process

Before the start of the designing the ball throwing machine we first made the 3D model of it. 3D model of the device can help us to better design the main body.

Figure 4.1: 3D design

Main body construction. First we made the bottom part of the main body with angle steel bars. Then we connected to it joining profile tubes.

Figure 4.2: Main body bottom part

Installing the motors. For this project we install the motors in a way that it is not replaceable. If we want to replace the motors we need to reconstruct the upper part of main body. Each motor is attached to it with four bolts and nuts. To decrease the impact of vibrations we put the rubber to the joining place. The next job is connecting the upper part which made from also steel angle bars.

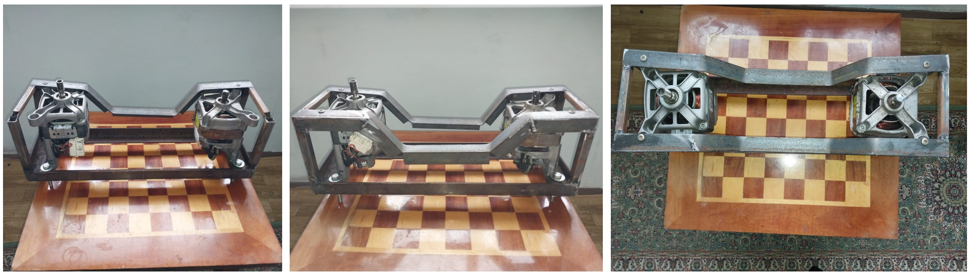


Figure 4.3: Installation of motors to main body

Installing the wheels. Wheel installing requires the accurate work when joining the shafts of the wheel and motor. If it is not correct levelled then there will be present vibrations. In the design process we met several times this kind of issues. I cope it with reinstalling the wheels and recentering them.

Figure 4.4: Main body with wheels and motors

4.0.2 Test Results

Speed Tests.
To measure the speed of the ball we need some professional tool. There are various technics and technologies to measure the ball speed. For instance the most suitable ones can be speed measuring with a high speed camera [17] and radar [18]. There was no access to these tools for us. Therefore we just used camera of smartphones with slow motion mode. This gave us rough approximations as shown in the figure. Our device could not give the speed results we expected. We wanted at least 70km/h, however we achieved only 40km/h. The main reason was that the

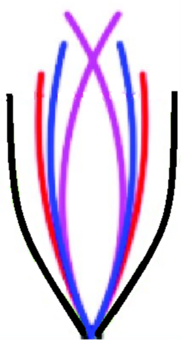
wheel rotation problem. The wheel itself could not handle high RPMs and main body construction caused many vibrations as we did have the professional and precise tools in the process of design.

100%*$\frac{V_{motor}}{V_{source}}$	Speed in km/h
25%	≈20km/h
50%	≈27km/h
75%	≈33km/h
100%	≈40km/h

Figure 4.5: Speed test results

Curved trajectory tests.

In today's football, free kicks are increasingly seen as key chances to score goals [19]. Skilled free kick specialists frequently choose to apply side spin to the ball, aiming to bend it into the goal. Curved trajectory of the kicked ball is achieved through the fact that the ball itself will have the rotational speed the effect of Magnus makes it to change its trajectory [20]. In the world of professional soccer game, players names it knuckle ball effect [21]. Our prototype could reach only small part of expected results in curving the ball trajectory. The main problem to this was the insufficient grip between ball and wheels. One more problem was that the curved trajectory can be achieved efficiently in higher speeds that we could not reach.



Wheel speed differences	Horizontal displacement
50%-75%	≈20cm
50%-100%	≈35cm
75%-100%	≈50cm
25%-100%	≈75cm

Figure 4.6: Curved trajectory test results

Chapter 5

Future works

In the future we will continue to develop the project further. Now, the prototype achieved the basic results and we know the problems we need to cope in order to make fully mobile and professional device. First we will update the wheels to those which are designated for high rotational speeds. We will update the main body to aluminum alloy material. Design process will include heat treatment and additive technologies. With proper wheels and motors we are planning to achieve maximum launch speed of 90km/h and curved trajectory [22]. Implementing the fully remote control of the device is also in our plan[23]. Furthermore after successfully making professional prototype we want to add the machine learning and computer vision elements to improve the players' skills much more efficiently and quicker[3].

Chapter 6

Conclusion

A successful development has been achieved in creating a soccer ball launching device. However we could get only the half of the values of the expected results, our prototype gave us very valuable experience and results which we will improve in our future plans .Various mechanical processes such as drilling, welding, threading, and grinding were employed in its construction. Currently, the machine is utilized for soccer games for smaller age groups as we could achieve speed parameters suitable for this group age. Future iterations will incorporate adjustability to accommodate different ball sizes. Additionally, enhancements will be made to the prototype using superior materials, and research will be conducted into integrating hub motors due to their promising potential. The machine operates by propelling several sizes of balls balls across the ground using motors and the counter-rotating motion of wheels. It enables launching of balls in both horizontal and vertical planes, as well as in trajectory motions, utilizing principles of aerodynamics and mechanics. This successful development allows for training of students in the goalkeeper area without the need for a trainer’s assistance.

Bibliography

[1] Mohd. Zain Uddin, undefined., et al. "Fabrication of Foot Ball Launcher Machine," 2020.

[2] Arslan, C., et al. "Ball Throwing Machine Design To Develop Footballers' Technical Attributes," in European Mechanical Science, vol. 5, pp. 39-43, 2021.

[3] J. Susila et al., 'Automatic Ball Launcher Machine for Goalkeeper Training Using YOLO Deep Learning Algorithm', in 2023 International Conference on Advanced Mechatronics, Intelligent Manufacture and Industrial Automation, ICAMIMIA 2023 - Proceedings, 2023, pp. 965–971.

[4] I.Raghuram, undefined. B.Susmitha. "Fabrication of Soccer and Cricket Ball Launching Machine," vol. 13, 2023.

[5] Paul J. Neilson. "The dynamic testing of soccer balls," 2003.

[6] Vogt, T., et al. "Football practice with youth players in the "Footbonaut"," in German Journal of Exercise and Sport Research, vol. 48, no. 3, pp. 341-348, 2018.

[7] T. Meyer, 'The Footbonaut as a new football-specific skills test: reproducibility and age-related differences in highly trained youth players', Science and Medicine in Football, vol. 3, no. 3, pp. 177–182, 2019.

[8] Beavan, J., Fransen, J., Spielmann, J., Mayer, J., Skorski, S., and Meyer, T. "The Footbonaut as a new football-specific skills test: Reproducibility and age-related differences in highly trained youth players. Science and Medicine in Football", 3(3), pp. 177-182, 2019.

[9] L. Barnabé, A. Volossovitch, R. Duarte, A. P. Ferreira, and K. Davids, 'Age-related effects of practice experience on collective behaviours of football players in small-sided games', Human Movement Science, vol. 48, pp. 74–81, 2016.

[10] Kevan Thorpe, "The Complete Guide to Football Sizes and Types", 2022. https://www.footy.com/blog/gear/football-size-guide/

[11] A. Rađa et al., ‘The ball kicking speed: A new, efficient performance indicator in youth soccer’, PLOS ONE, vol. 14, no. 5, pp. 1–11, 05 2019.

[12] Alon Singh, Amirali Farzaneh, Jagpreet Grewal, et al. "DESIGN SPECIFICATION: REVISION A KICKPRO", IronFoot Technologies, 2023.

[13] Mohd Hasnun, Arif Hassan, Zahari Taha, Mohd Ali Hanafiah Shaharudin, Lim Kok Wee, Zulfika Anuar, ‘Development of a Soccer Ball Launching Device’, Intelligent Manufacturing and Mechatronics, pp. 591-598, 2018.

[14] M. Yüksel, S. Losch, S. Kroffke, M. Rohn and F. Kirchner, "BLDC wheel hub motor and motor controller performance test of a concept electric robotic vehicle in HIL according to real driving characteristics," 2015 9th International Conference on Electrical and Electronics Engineering (ELECO), Bursa, Turkey, 2015, pp. 613-617, doi: 10.1109/ELECO.2015.7394578.

[15] S. Natarajan, K. Balasubramanian, P. R. Satpathy and T. S. Babu, "Universal Motor with On-Off Controller for Washing Machine Application," 2021 International Conference in Advances in Power, Signal, and Information Technology (APSIT), Bhubaneswar, India, 2021, pp. 1-6, doi: 10.1109/APSIT52773.2021.9641321.

[16] Andrew James Marquette, "Design and Construction of an Omni-Directional Soccer Ball Thrower", Undergraduate Honors Capstone Projects, Utah State University, 2013.

[17] Martin, Jason John. “Evaluation of Doppler Radar Ball Tracking and Its Experimental Uses.” Washington State University, 2012.

[18] Ahmad, Masniezam, et al. "Velocity measurement of a sports ball during the drop test by a high-speed camera." Int J Mech Eng Robot Res 8.2, 2019, pp. 273-278.

[19] J. Castellano, D. Casamichana, C. Lago. "The use of match statistics that discriminate between successful and unsuccessful soccer teams," in Journal of human kinetics, vol. 31, no. 2012, pp. 137–147, 2012.

[20] Craig, C., et al. "Judging where a ball will go: the case of curved free kicks in football," in Naturwissenschaften, vol. 93, pp. 97–101, 2006.

[21] Eager, D., et al. "Investigating the knuckleball effect in soccer using a smart ball and training machine," in Sensors, vol. 22, no. 11, pp. 3984, 2022.

[22] Goff, J., et al. "Creating drag and lift curves from soccer trajectories," in European Journal of Physics, vol. 38, no. 4, pp. 044003, 2017.

[23] Negron, I., et al, "SkillCourt Autonomous Ball Launcher," in 30th Florida Conference on Recent Advances in Robotics, 2017.

[24] d'Avella, A., et al. "A new ball launching system with controlled flight parameters for catching experiments," in Journal of neuroscience methods, vol. 196, no. 2, pp. 264–275, 2011.

[25] Supriadi, A., et al. "The Effect of Learning Manipulative Skills Using Ball Thrower Learning Media on the Ability to Throw and Catch the Ball in Elementary School Students," in International Journal of Education in Mathematics, Science and Technology, vol. 10, no. 3, pp. 590–603, 2022.