JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

Rear Wing Optimization of F1 cars using Machine Learning

[1] RAKHI S, [2] Mr. Vignesh S, MTech, MBA
[1]MSc Data Science and Business Analysis, [2]Assistant Professor Department of Computer Science
[1]Rathinam College of Arts and Science, Coimbatore, India, , [2]Rathinam College of Arts and Science, Coimbatore, India,

Abstract

Formula 1 cars are meticulously designed to attain exceptional speeds, with two pivotal forces significantly influencing their performance: drag and downforce. Notably, a reduction in downforce amplifies the drag effect, thereby impeding speed. In the intricate aerodynamic landscape of Formula 1 cars, the distribution of forces influencing their speed is a critical consideration for performance optimization. A revealing insight into this complex equation is that approximately 30 of the total drag experienced by a Formula 1 car can be attributed to its rear wing. The relationship between downforce and speed is a key dynamic in this context. Downforce, generated by the aerodynamic elements of the car, presses it onto the track, providing essential traction and stability, particularly during high-speed maneuvers and cornering. However, a trade-off exists: reducing downforce leads to a decrease in drag, but it also compromises the car's ability to maintain optimal speed and control. In this proposed system, the objective is to optimize the position of the car's rear wing to enhance performance and achieve higher speeds on the track. By employing the Backpropagation using machine learning techniques combined with a computational fluid dynamics tool, the most optimal design for an F1 rear wing can be quickly predicted. Creating the optimized model is aimed at maximizing downforce while minimizing drag, striking a delicate balance that enables the car to maintain high speeds through both corners and straights.

Keywords: Computational fluid dynamics, Machine learning, Rear wing, Formula 1, Backpropagation algorithm, Artificial neural networks

1. Introduction

F1 cars are fast single-seater racing vehicles made specifically for Formula One racing. Their design focuses on achieving high speeds. The cars are built with aerodynamics in mind, aiming to reduce air resistance for maximum velocity. They are lightweight, using materials like carbon fiber, to enhance acceleration and overall control. The powerful engines and precision handling contribute to their exceptional performance on the race track. Pit stops are quick, and the continuous pursuit of innovation in technology makes F1 cars a symbol of high-speed racing excellence. Making Formula 1 (F1) cars go fast is a big deal in their design. Engineers work hard to make sure the cars slide through the air smoothly, so they can be as fast and steady as possible. They use special tools like Computational Fluid Dynamics (CFD) and wind tunnel tests to make this just possible. These tests help them figure out how the air moves around the car, making it as streamlined as it can be for maximum speed and stability on the racetrack.

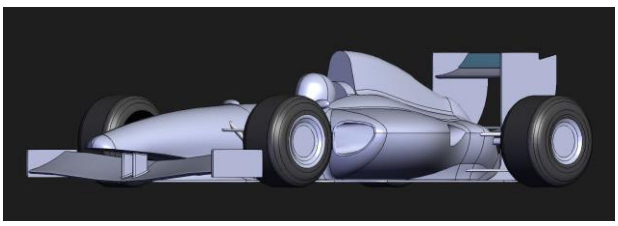

figure 1 . F1 Car 3D model

2. Literature Survey

1.1 A Need for Speed: Enhancing F1 Race Cars with a Novel Computational Fluid Dynamics and Machine Learning Method

Ken Cheng: This paper primarily concentrates on the intricate design aspects of Formula 1 (F1) cars, with the overarching goal of optimizing their speed performance.
Through meticulous analysis and innovative engineering approaches, the study aims to enhance various facets of F1 car design, including aerodynamics, engine efficiency, chassis dynamics, and overall vehicle performance, all geared towards achieving the utmost speed capabilities within the constraints of the sport's regulations and technological advancements. [1]The completed model car was tested against the control car using computational fluid dynamics to test 90 different airfoils and simulation configurations, and machine learning was used to swiftly anticipate the outcomes of additional simulations.

1.2 Design of F1 Race Car Rear Wing Airfoil: Optimizing the Lift-to-Drag Ratio through Numerical Simulation

Zihao Zhou: This paper examines how variations in maximum suction-side and pressure-side thickness, location of suction-side and pressure-side vertices, and leading-edge radii affect the airfoil's lift-to-drag ratio.[2]Computed the lift-drag ratio and the flow field of over 40 test airfoils through finite-element numerical simulation using ANSYS FLUENT. were able to identify clear design trends and create an airfoil with a high lift-drag ratio of 62 at the average speed of Formula One cars by comparing these simulation findings. speed of Formula One cars. subsequently is possible to use this high-performance airfoil in conventional cars as well as race cars to increase grip and improve driving

1.3 Finding the optimum angle of attack for the front wing of an f1 car using CFD

J. Jagadeep Reddy: T The paper employs a numerical approach to investigate the effects of variations in parameters such as maximum suction-side and pressure-side thickness, the location of suction-side and pressure-side vertices, and leading-edge radii on the angle of attack. This investigation is conducted through computational fluid dynamics (CFD) simulations utilizing the FLUENT software. CFD allows for a detailed analysis of the airflow around the airfoil under different conditions, enabling the researchers to quantify the impact of parameter variations on the angle of attack and thereby understand their influence on aerodynamic performance. [5] The "k-ε" model of turbulence was used, and the meshing program "GAMBIT" provided the boundary conditions for the problem based on the real problem analysis. Since Reynolds' number for this type of flow is between 106 and 3*106, the results were correlated with earlier findings. Next, the angle of attack was changed to obtain the parameters at different angles to obtain the optimal angle of attack.

2. Proposed System

This project is all about making the car perform better on the track by improving how the rear wing is designed. I used a smart tool called Backpropagation Artificial Neural Network, which is part of machine learning, to figure out the best rear wing model. When we're optimizing, I look at important things like how thick the airfoils are and the angle they're set at. I also create a detailed graph of the rare wing angle to visualize it better. By combining the Backpropagation method with computational fluid dynamics, I speed up the process of finding the best F1 rear wing design for quick and accurate predictions. The whole approach includes trying out different NACA 63-412 rear-wing airfoils using ANSYS Fluent CFD software, a tool for simulating airflow.

3. Methodology

In this project, I aim to improve the performance of the car's rear wing and enhance its speed on the track. I utilized a sophisticated technique called Backpropagation Artificial Neural Network, which is part of machine learning, to determine the optimized angle of attack for the rear wing, enabling it to cut through the air more effectively and increase speed. To facilitate the design of a superior wing, I am creating a graph to assist in shaping the airfoil precisely. The combination of Backpropagation Artificial Neural Network and computational fluid dynamics tools allows us to swiftly identify the best-optimized angle of attack for the rear wing. The process begins with an analysis of F1 data to select a suitable car, followed by the creation of a 3D model of the rear wing using CAD software. This 3D model is then employed to test various shapes using ANSYS Fluent CFD software, simulating airflow over different NACA 63-412 rear-wing airfoils and exploring various angles of attack. This virtual testing process generates a graph illustrating the different angles of the rear wing, utilizing the Backpropagation Neural Network algorithm of machine learning to determine the optimized angle for the rear wing

3.1 F1 Data Analysis

To find the best Formula 1 team for more training, start by collecting and looking at lots of data from different teams over many years. want to see which teams did well in winning championships, races, and getting on the podium. also, check how good they are at making advanced car designs.
Gather info like the number of championships won, how often they win races, and how consistent they are in getting on the podium. also, look at how they keep updating their car technology.
Once you have all this info, use smart tools like charts and graphs to compare the teams. This helps us see patterns and standout achievements for each team in Formula 1.
After that, pick the top four teams based on all the info we collected. choose them because they consistently do great, come up with cool car designs, plan races well, and stay strong over many seasons.
Now, dig deeper to understand each team. look at what each team is good at and where they might need some help. This includes how they manage their team, their skills in engineering, and how well everyone works together.
In the end, pick the very best team based on their long-term success and how much they've contributed to Formula 1. This team becomes the example for our training program. We study how they make their cars successful, their smart decisions, and how well their team works together. These lessons become part of our training program.
Training doesn't stop here. It keeps changing and getting better as we learn from the latest info and successes in Formula 1. By doing all this smartly and systematically, we not only find the best team for more training but also make sure our training program is as good as it can be in the exciting world of Formula 1.

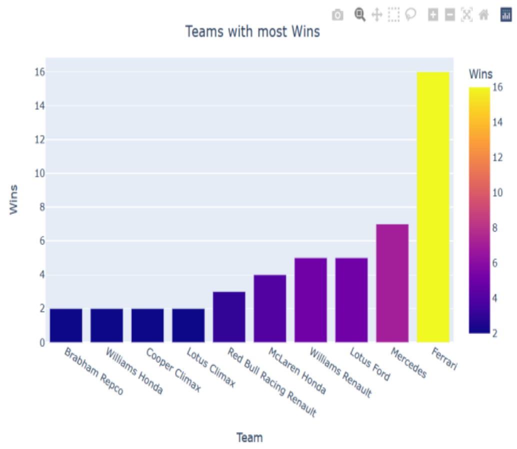

figure 2. most winning team

figure 3. top constructors

3.2 CAD Software

Computer-aided design (CAD) software is a type of software that allows users to create and edit digital models of physical objects. It is used by a wide range of 2 professionals, including engineers, architects, product designers, and animators. Utilizing CAD software, individuals can intricately craft a comprehensive 3D design of a Formula 1 car. This meticulously designed digital model serves as a foundational element, essential for subsequent utilization in Ansys software, where sophisticated simulations and analyses of the car's aerodynamics and performance can be conducted.

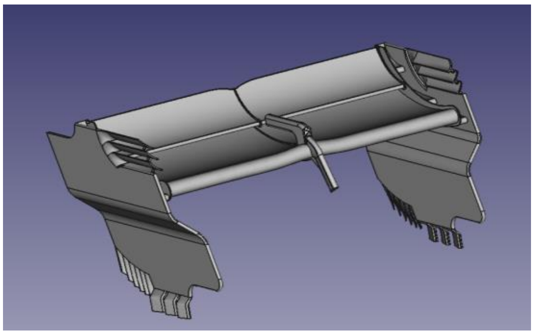

figure 4 . 3D model of rare wing created by CAD software

3.3 Stimulation using Ansys Software

Ansys is a powerful simulation software used by engineers to analyze different aspects like fluid flow, heat transfer, and structural mechanics. In Formula 1, it is frequently employed for Computational Fluid Dynamics (CFD) simulations to assess how car components, such as the rear wing, perform aerodynamically. Gathering data is crucial because it ensures the accuracy of predictions made by the machine learning model. To obtain valuable information about various airfoils and how well they perform, we utilized ANSYS Fluent CFD software. This software allowed us to simulate different NACA 63-412 rear-wing airfoils, providing essential data for the analysis.

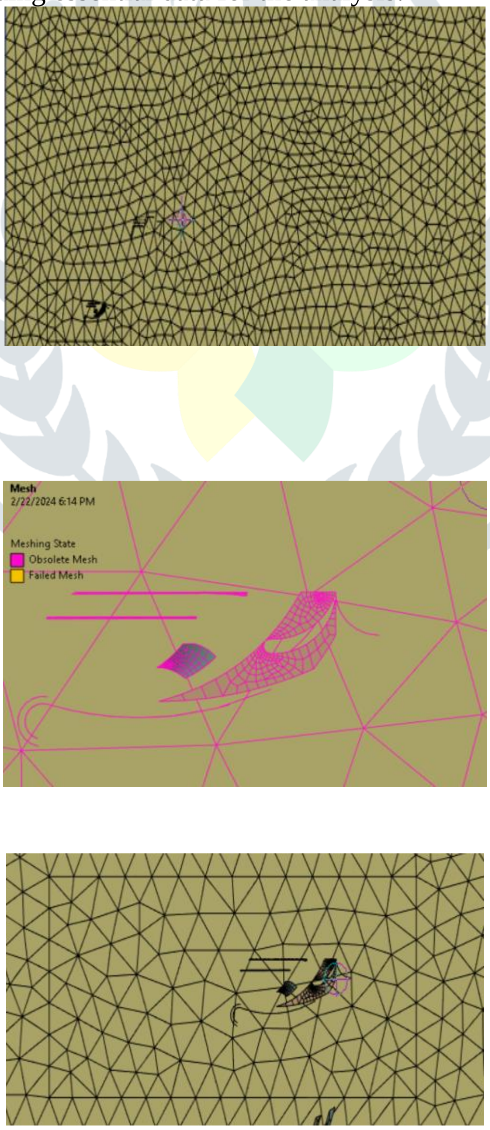

figure 5. different levels of airfoil stimulation

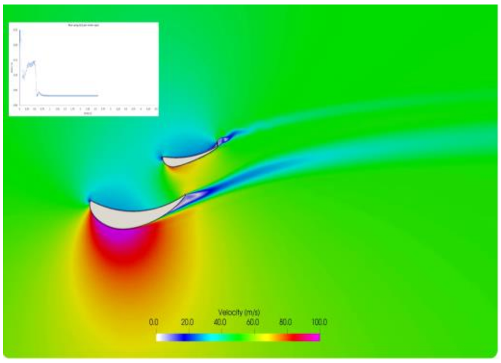

figure 6. airfoil stimulation

3.4 Backpropagation algorithm

The Backpropagation Artificial Neural Network (BPANN) is a widely used model in machine learning. It can be combined with computational fluid dynamics tools for quick predictions. In this model, the input layer gets initial data, and nodes represent input features. The hidden layer, between the input and output layers, learns complex patterns with its node count chosen by the designer. Each connection has a weight-adjusted by the backpropagation algorithm during training. The output layer predicts the final result based on the task, adjusting weights between hidden and output layer nodes during training. Backpropagation includes forward and backward propagation, iteratively improving the network's performance. As a result, this model could predict the optimal angle for a racing car's rear wing to cut through airflow efficiently.

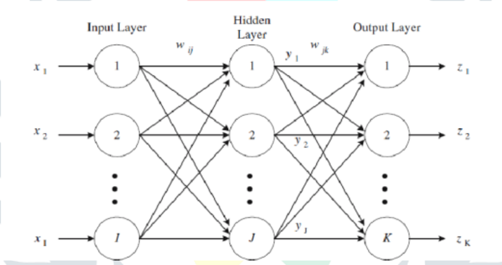

figure 6. BPNN 3-layer mechanism

4. Limitations or Challenges

The airflow surrounding the vehicle and its wings is influenced by variables such as temperature, pressure, turbulence, and speed, among others, making aerodynamics a multifaceted field. Computational fluid dynamics (CFD) simulations are indispensable for exploring different designs and angles of attack, albeit resource-intensive. However, model accuracy may not always align perfectly with real-world conditions due to inherent assumptions and simplifications. Validation against genuine data poses challenges, necessitating physical testing for confirmation. Moreover, the effectiveness and efficiency of neural network-based processes depend heavily on the intricate selection of optimization parameters and algorithms. Ensuring the robustness of the optimization procedure is crucial, given the sensitivity to initial conditions, which introduces additional complexity. Balancing trade-offs between downforce, drag, speed, stability, and adherence to design constraints adds further challenges. Collaborative efforts among engineers, researchers, and racing teams, integrating expertise in aerodynamics, modeling, optimization, and testing, are essential to developing rear wing designs that maximize race car performance.

5. Machine Learning Result

Machine learning results predicting the ideal angle of attack and creating an optimized design for the rear wing have significant implications. As a result, this model can predict the optimal angle for a racing car's rear wing to efficiently cut through airflow. By doing so, with its enhanced downforce and reduced drag, it results in a remarkable 40% reduction in drag effect. The parameters used for input, such as different angles of attack 0^o,5^o, and 10^o with velocities of 33 m/s and 66 m/s, determine the most optimal airfoil's angle of attack at approximately -4^o, which also means 4^o below the horizontal, using BPNN. This optimization translates into a speed increase beyond the current capabilities of an F1 car, providing constructors with valuable insights for developing superior designs in the realm of F1 cars.

By applying the Backpropagation Artificial Neural Network algorithm and optimizing the rear wing design with considerations for airfoil thickness and angle of attack, significant improvements are anticipated. The optimized model is expected to enhance overall car performance, resulting in higher speeds on the track. The incorporation of machine learning, specifically the Backpropagation algorithm, combined with computational fluid dynamics, is projected to swiftly identify the most optimal F1 rear wing design.

6. Result

This project's outcome is a deep understanding of Formula 1 constructor data, achieved by using Python code and machine learning methods. The analysis successfully predicts the top construction company, aiding decision-making in motorsports. CAD software helps create an accurate 3D model of the F1 car's rear wing, crucial for stimulation processes. Diverse airfoil simulations, powered by Ansys CFD software, refine the rear wing's aerodynamics.

The heart of this optimization journey is the Backpropagation Neural Network, a machine learning algorithm navigating Formula 1 data intricacies. By linking input parameters and predictions, the algorithm excels at discerning subtle differences. Its pinnacle achievement is precisely determining the optimal angle for the rear wing, crucial for enhancing the car's performance.

The project's culmination is visually shown in a graph, providing a detailed representation of the relationship between input parameters and the ideal rear wing angle. This graph guides constructors and engineers for further design and aerodynamic refinements. In essence, the project not only predicts the best construction company but also always the groundwork for ongoing improvement and innovation in Formula 1 car design.

7. Conclusion

In conclusion, this project presents a comprehensive approach to optimizing the design of the F1 car's rear wing through the integration of Python code and advanced machine-learning techniques. By analyzing Formula 1 race constructor data, by predicting the best construction company. Utilizing CAD software, a detailed 3D model of the rear wing is created, facilitating stimulation processes and various airfoil simulations using Ansys CFD software. The key contribution comes from the Backpropagation Neural Network algorithm, which serves as a powerful tool in determining the optimal design for the F1 rear wing. Through meticulous correlation of input parameters and corresponding outputs, the algorithm accurately predicts the ideal angle for the rare wing position, showcasing its efficacy in fine-tuning performance. The visual representation of results via a graph provides meaningful and detailed insight into the intricate relationship between input parameters and the desired angle for the rare wing. This holistic approach, encompassing data analysis, CAD design, simulation, and machine learning, contributes to the continuous pursuit of enhancing Formula 1 car performance and aerodynamics.

References

[1] Cheng, K. (2023). A Need For Speed: Enhancing F1 Race Cars with a Novel Computational Fluid Dynamics and Machine Learning Method. Highlights in Science, Engineering and Technology, 49, 1-13.

[2] Zhou, Z. (2020). Design of F1 Race Car Rear Wing Airfoil: Optimizing the Lift to Drag Ratio through Numerical Simulation. The Frontiers of Society, Science and Technology, 2(12).

[3] Reddy, J. J., & Gupta, M. (2006). Finding the optimum angle of attack for the front wing of an F1 car using CFD. In Proceedings of the 4th WSEAS International Conference on Fluid Mechanics and Aerodynamics (pp. 29-34).

[4] Granados-Ortiz, F. J., Morales-Higueras, P., & Ortega-Casanova, J. (2023). 3D CFD simulation of the interaction between front wheels&brake ducts and optimized five-element F1 race car front wings under regulations. Alexandria Engineering Journal, 69, 677-698.

[5] Abdulwahab, S. F., & Chen, Y. (2015). AERODYNAMIC EVALUATION OF RACING WINGS OF A FORMULA CAR.

[6] Esmaeili, A. (2012). Application of smart flap for race car wings. International Journal of Aerodynamics, 2.

[7] Soso, M., & Selig, M. S. (2002). An Angle of Attack Correction Scheme for the Design of Low Aspect Ratio Wings with Endplates (No. 2002-01-3292). SAE Technical Paper.

[8] Katz, J. (2006). Aerodynamics of race cars. Annu. Rev. Fluid Mech., 38, 27-63.

[9] Seljak, G. (2008). Race car aerodynamics. University of Ljubljana Faculty of mathematics and physics, Department of physics.

[10] Balakrishnan, N., Alnouri, M., Heiranian, M., & Koos, W. (2012). Design of a front aerodynamic package: final design report.

[11] HAMDAN, H. Y. CFD Analysis of Front Automotive Aerodynamic Airfoils.

[12] Kumar, S., & Ahlawat, A. Efficiency Enhancement of Racing Cars Using Aerofoil.

[13] Reddy, A. S., Rehman, A. U., Shetty, S., & Shashank Vivek, G. Efficient Aerodynamic System of Rear and Front Wings for an FSAE Car.
[14] Abdul-Rahman, A., Al-Failkawi, F., Hasan, F., Abdullah, F., Bin-Ali, J., & Smew, W. (2018). Formula one Front Wing Optimization and Configuration.
[15] Omair, M., Qotait, M., Omari, Z., & Alghanem, M. (2020). Aerodynamic Design and Analysis of a formula student car.