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LEVERAGING MACHINE LEARNING TO OPTIMIZE PRODUCTION PROCESSES AND CAPACITY IN THE BREWERY INDUSTRY

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Abstract: The decrease in the production capacity that had crippled business activities that mostly depend on drinks to run their daily activities was overcame by introducing leveraging machine learning to optimize production processes and capacity in the brewery industry, to perfectly achieve this, it was done in the approach, characterizing and establishing the causes of poor production capacity in a brewery industry, designing a conventional SIMULINK model for production processes in the brewery industry, designing leverage machine learning rule base that will reduce the causes of poor production capacity in a brewery industry and simultaneously increase the production capacity, training ANN in the designed machine learning rule base for effective reduction of the causes of poor production capacity in a brewery industry and simultaneously increase the production capacity, designing a SIMULINK model for leverage machine learning, developing an algorithm that will implement the process, designing a SIMULINK model for leveraging machine learning to optimize production processes and capacity in the brewery industry and validating and justifying the percentage improvement in the production capacity of a brewery industry with and without leveraging machine learning. The results obtained were the conventional inefficient Process Control and Automation, caused by poor production capacity in the brewery industry was 20%. On the other hand, when leveraging machine learning was introduced in the system, it drastically reduced inefficient Process Control and Automation, causing poor production capacity in the brewery industry to 17.34%. Thereby enhancing the production capacity, the conventional Lengthy Fermentation and Maturation Times caused poor production capacity in the brewery industry was 10%. Meanwhile, when machine learning was incorporated into the system, it decisively reduced Lengthy Fermentation and Maturation Times caused by poor production capacity in the brewery industry to 8.7%, and the conventional production capacity in the brewery industry was 50000 bottles of drink. On the other hand, when machine learning was inculcated in the system, it simultaneously enhanced the production capacity in the brewery industry to 6500 bottles of drink. Finally, with these results obtained, it showed that production capacity in the brewery industry was optimized by 33%...

Keywords: Learning, Leveraging, Machine, Processes, Production

1.1 Introduction

The brewery industry is highly competitive, with manufacturers continually seeking ways to optimize production processes, minimize waste, and maximize production capacity. Traditional methods of process optimization in breweries rely heavily on manual observations, fixed schedules, and historical data that may not adapt swiftly to changing conditions (Rathore & Tiwari, 2020). In recent years, machine learning (ML) has emerged as a transformative technology in industrial manufacturing, offering advanced data-driven solutions that significantly improve process control and forecasting capabilities (Zhou et al., 2021). Machine learning algorithms can analyze large volumes of production data in real time, providing insights that enhance decision-making, streamline operations, and improve resource utilization (Wuest et al., 2019). The brewery industry, due to its complex manufacturing processes involving various stages such as fermentation, bottling, and packaging, is uniquely positioned to benefit from machine learning applications. These algorithms can optimize fermentation times, monitor quality control in real-time, and adjust operations dynamically based on demand and resource availability (Oliveira & Cunha, 2019). Furthermore, machine learning supports predictive maintenance, reducing equipment downtime and minimizing disruptions in production cycles (Agrawal et al., 2020). Given the need for sustainable operations, machine learning also contributes to achieving energy efficiency, which aligns with industry goals to minimize environmental impact (Lydon et al., 2021). However, integrating machine learning into brewery production faces several challenges, including the need for significant data infrastructure, skilled personnel, and an understanding of the nuances of applying AI-based solutions to traditional processes (Singh & Kumar, 2021). Despite these challenges, the potential benefits have spurred research into developing tailored ML models that address the specific needs of the brewing industry. This study aims to explore how machine learning can be effectively leveraged to optimize production processes and increase capacity within breweries, ultimately contributing to a more sustainable, efficient, and competitive brewing industry.

The research aims to explore the application of machine learning in optimizing production processes and enhancing capacity in the brewery industry. The specific objectives are as follows:

1. To characterize and establish the causes of poor production capacity in the brewery industry.
2. To design a conventional SIMULINK model for production processes in the brewery industry
3. To design leverage machine learning rule base that will reduce the causes of poor production capacity in the brewery industry and simultaneously increase the production capacity.
4. To train ANN in the designed machine learning rule base for effective reduction of the causes of poor production capacity in the brewery industry, and simultaneously increase the production capacity
5. To design a SIMULINK model to leverage machine learning
6. To develop an algorithm that will implement the process
7. To design a SIMULINK model for leveraging machine learning to optimize production processes and capacity in the brewery industry.
8. To validate and justify the percentage improvement in the production capacity of a brewery industry with and without leveraging machine learning
9. To analyze current production processes in the brewery industry and identify key areas where machine learning can improve efficiency and optimize resource utilization.
10. To develop and implement machine learning models that predict and control critical production parameters, such as fermentation time, bottling rates, and quality consistency.

11. To evaluate the impact of machine learning on predictive maintenance for brewery equipment, with a focus on reducing downtime and improving production continuity.
12. To assess the potential of machine learning in optimizing scheduling and resource allocation within brewery operations to maximize production capacity.
13. To investigate how machine learning can be applied to monitor and maintain the quality of raw materials and final products, ensuring consistent quality and minimizing variability.
14. To explore the role of machine learning in energy management within brewery operations, focusing on achieving energy efficiency and reducing production costs.
15. To provide a framework or set of best practices for integrating machine learning technologies in brewery production processes, facilitating scalability and long-term operational benefits.

Through these objectives, the study aims to provide valuable insights into how machine learning can be effectively leveraged to optimize production processes and capacity, ultimately enhancing competitiveness and sustainability within the brewery industry.

2.0 Methodology

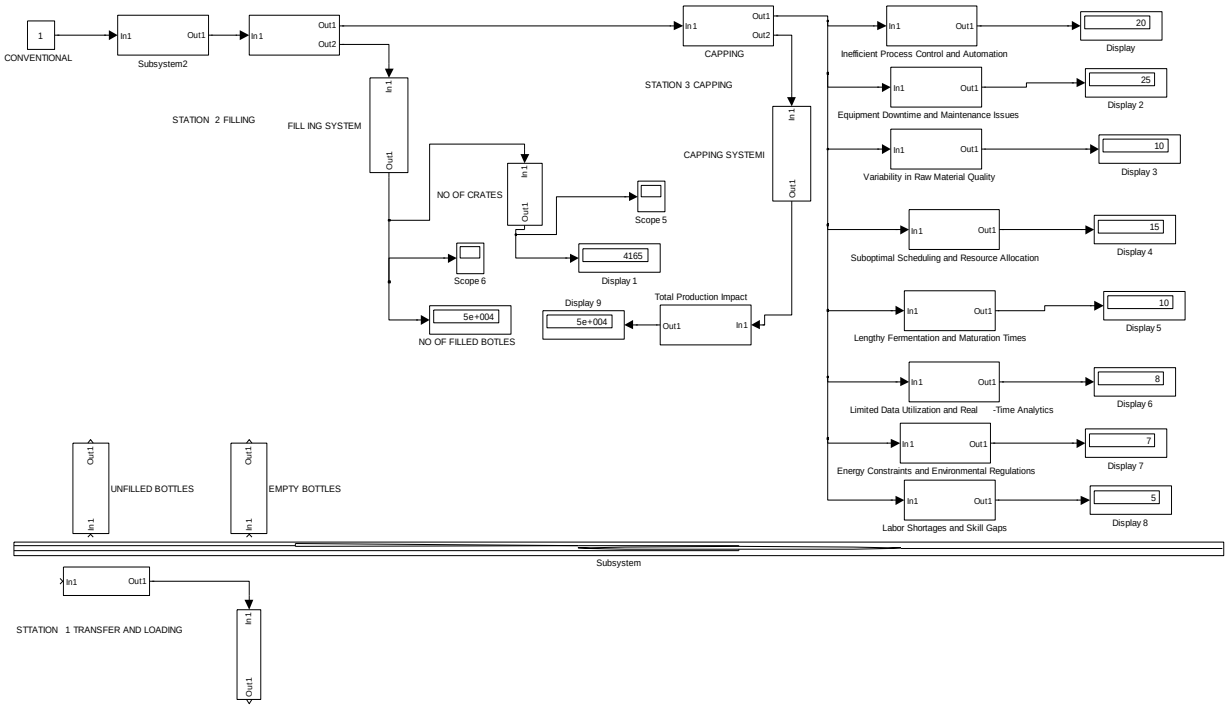
To characterize and establish the causes of poor production capacity in the brewery industry.

Here's an example of how poor production capacity in the brewery industry can be characterized by causes, with percentages and their corresponding impact in terms of bottles of drinks produced per day:

Cause of Poor Production Capacity	Impact (%)	Impact (Number of Bottles per Day)
Inefficient Process Control and Automation	20%	10,000 fewer bottles
Equipment Downtime and Maintenance Issues	25%	12,500 fewer bottles
Variability in Raw Material Quality	10%	5,000 fewer bottles
Suboptimal Scheduling and Resource Allocation	15%	7,500 fewer bottles
Lengthy Fermentation and Maturation Times	10%	5,000 fewer bottles
Limited Data Utilization and Real-Time Analytics	8%	4,000 fewer bottles
Energy Constraints and Environmental Regulations	7%	3,500 fewer bottles
Labor Shortages and Skill Gaps	5%	2,500 fewer bottles
Total Production Impact	100%	50,000 fewer bottles

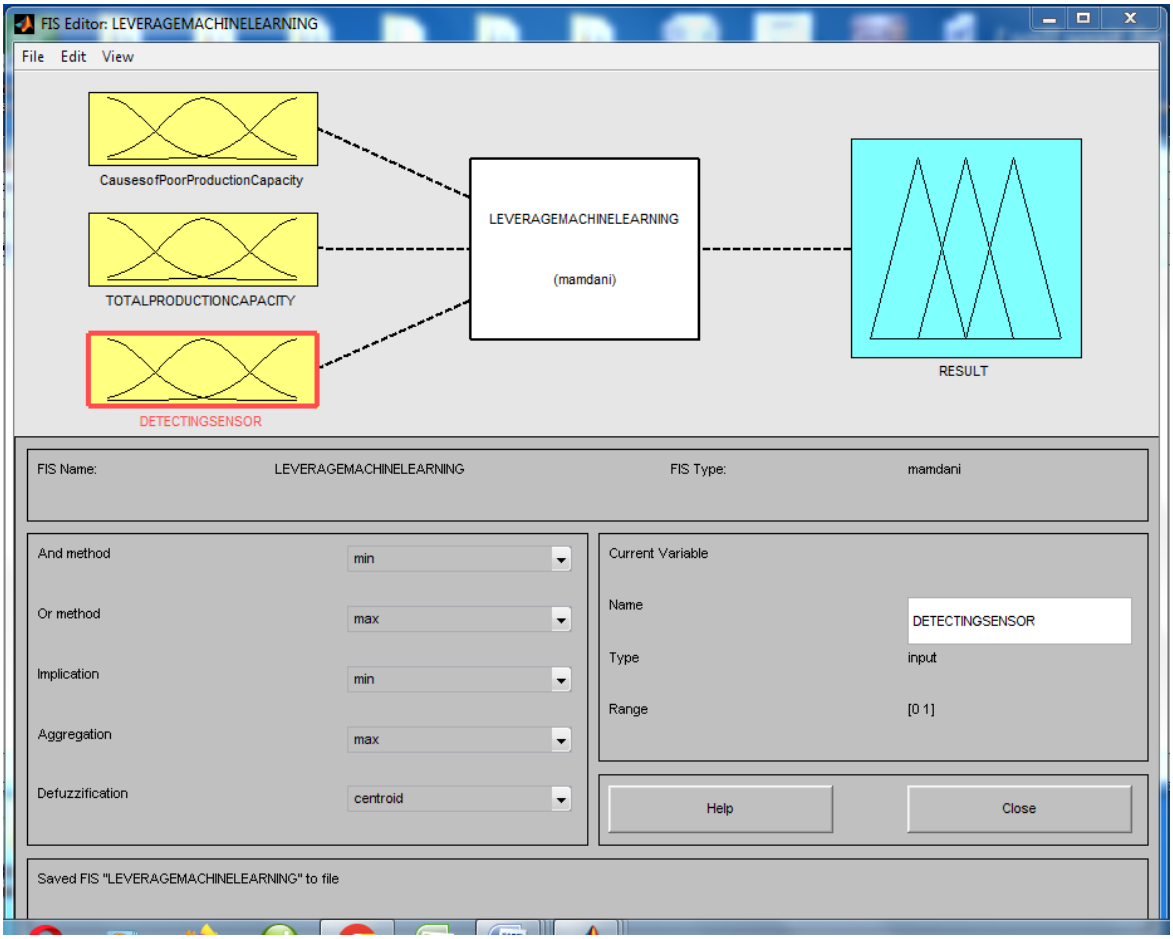
Explanation**:**

- The table indicates the estimated contribution of each cause to the reduction in production capacity, expressed as a percentage and in terms of the reduction in bottles of drinks produced per day.
- These values are estimates and may vary based on the specific brewery's production environment and operational parameters.



To design a conventional SIMULINK model for production processes in the brewery industry.

To design a machine learning rule base that will reduce the causes of poor production capacity in a brewery industry and simultaneously increase the production capacity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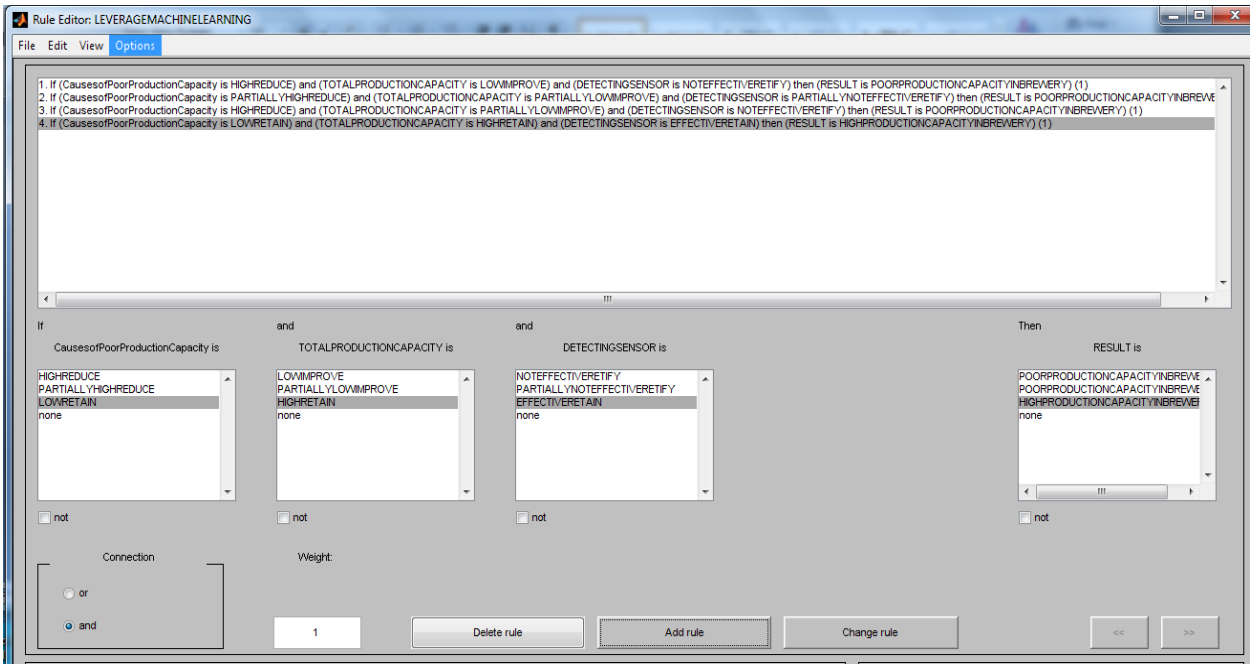
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1. If (CausesofPoorProductionCapacity is HIGHREDUCE) and (TOTALPRODUCTIONCAPACITY is LOWIMPROVE) and (DETECTINGSENSOR is NOTEFFECTIVERETIFY) then (RESULT is POORPRODUCTIONCAPACITYINBREWERY) (1)
2. If (CausesofPoorProductionCapacity is PARTIALLYHIGHREDUCE) and (TOTALPRODUCTIONCAPACITY is PARTIALLYLOWIMPROVE) and (DETECTINGSENSOR is PARTIALLYNOTEFFECTIVERETIFY) then (RESULT is POORPRODUCTIONCAPACITYINBREWE
3. If (CausesofPoorProductionCapacity is HIGHREDUCE) and (TOTALPRODUCTIONCAPACITY is PARTIALLYLOWIMPROVE) and (DETECTINGSENSOR is NOTEFFECTIVERETIFY) then (RESULT is POORPRODUCTIONCAPACITYINBREWERY) (1)
4. If (CausesofPoorProductionCapacity is LOWRETAIN) and (TOTALPRODUCTIONCAPACITY is HIGHRETAIN) and (DETECTINGSENSOR is EFFECTIVERETAIN) then (RESULT is HIGHPRODUCTIONCAPACITYINBREWERY) (1)
If
CausesofPoorProductionCapacity is
HIGHREDUCE
PARTIALLYHIGHREDUCE
LOWRETAIN
none
and
TOTALPRODUCTIONCAPACITY is
LOWIMPROVE
PARTIALLYLOWIMPROVE
HIGHRETAIN
none
and
DETECTINGSENSOR is
NOTEFFECTIVERETIFY
PARTIALLYNOTEFFECTIVERETIFY
EFFECTIVERETAIN
none
Then
RESULT is
POORPRODUCTIONCAPACITYINBREWE
POORPRODUCTIONCAPACITYINBREWE
HIGHPRODUCTIONCAPACITYINBREWE
none
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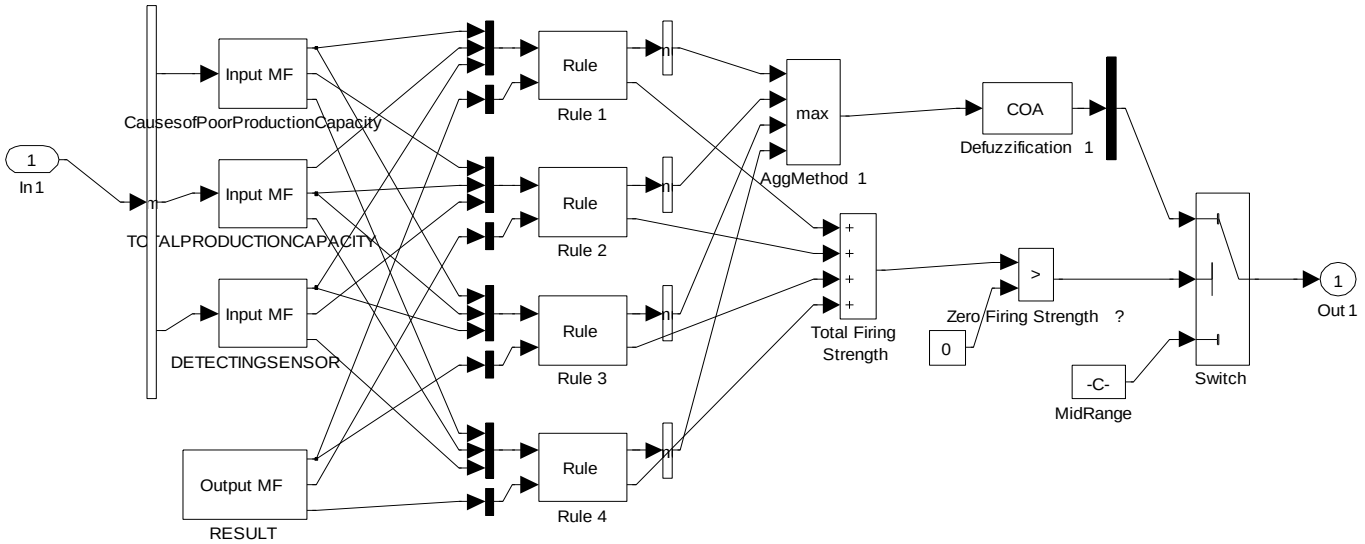
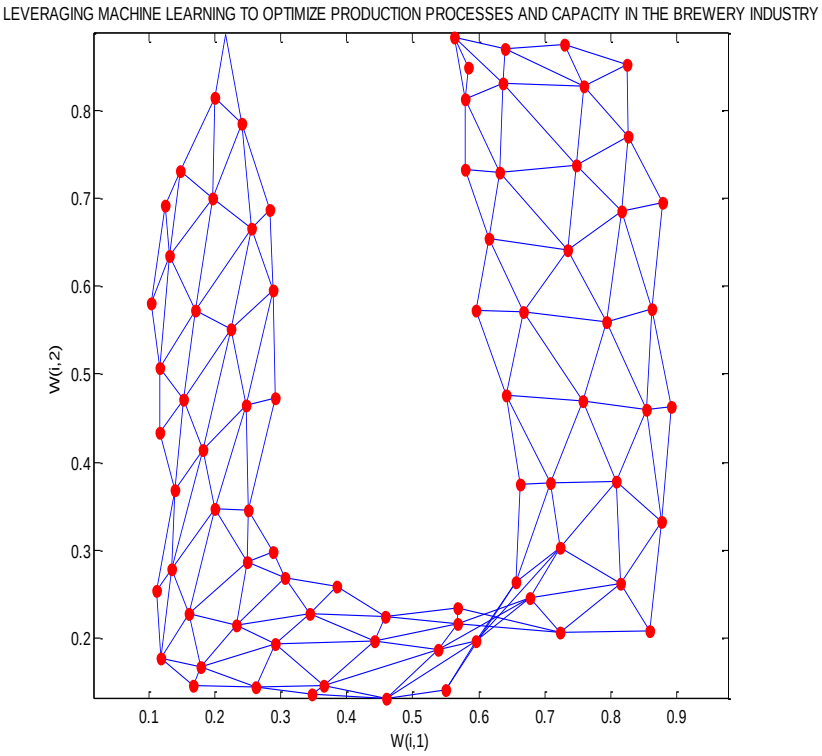
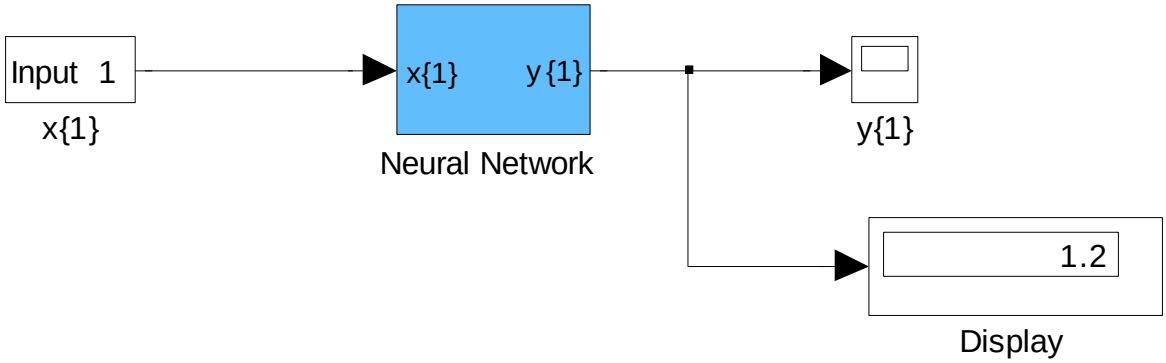
1	IF THE CAUSES OF POOR PRODUCTION CAPACITY ARE HIGH REDUCE	AND TOTAL PRODUCTION CAPACITY IS LOW IMPROVE	AND DETECTING SENSOR IS NOT EFFECTIVE RECTIFY	THE RESULT IS POOR PRODUCTION CAPACITY IN THE BREWERY INDUSTRY
2	IF THE CAUSES OF POOR PRODUCTION CAPACITY ARE PARTIALLY HIGH REDUCE	AND TOTAL PRODUCTION CAPACITY IS PARTIALLY LOW IMPROVE	AND DETECTING SENSOR IS PARTIALLY NOT EFFECTIVE RECTIFY	THE RESULT IS POOR PRODUCTION CAPACITY IN THE BREWERY INDUSTRY
3	IF THE CAUSES OF POOR PRODUCTION CAPACITY ARE HIGH REDUCE	AND TOTAL PRODUCTION CAPACITY IS PARTIALLY LOW IMPROVE	AND DETECTING SENSOR IS NOT EFFECTIVE RECTIFY	THE RESULT IS POOR PRODUCTION CAPACITY IN THE BREWERY INDUSTRY
4	IF THE CAUSES OF POOR PRODUCTION CAPACITY ARE LOW RETAIN	AND TOTAL PRODUCTION CAPACITY IS HIGH RETAIN	AND DETECTING SENSOR IS EFFECTIVE RETAIN	THE RESULT IS HIGH PRODUCTION CAPACITY IN THE BREWERY INDUSTRY

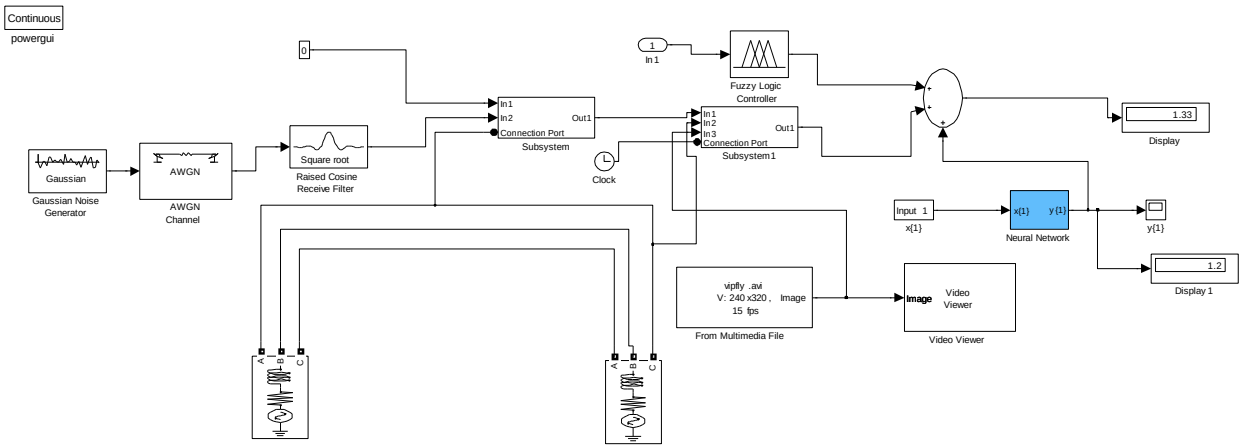


To train ANN in the designed machine learning rule base for effective reduction of the causes of poor production capacity in a brewery industry and simultaneously increase the production capacity





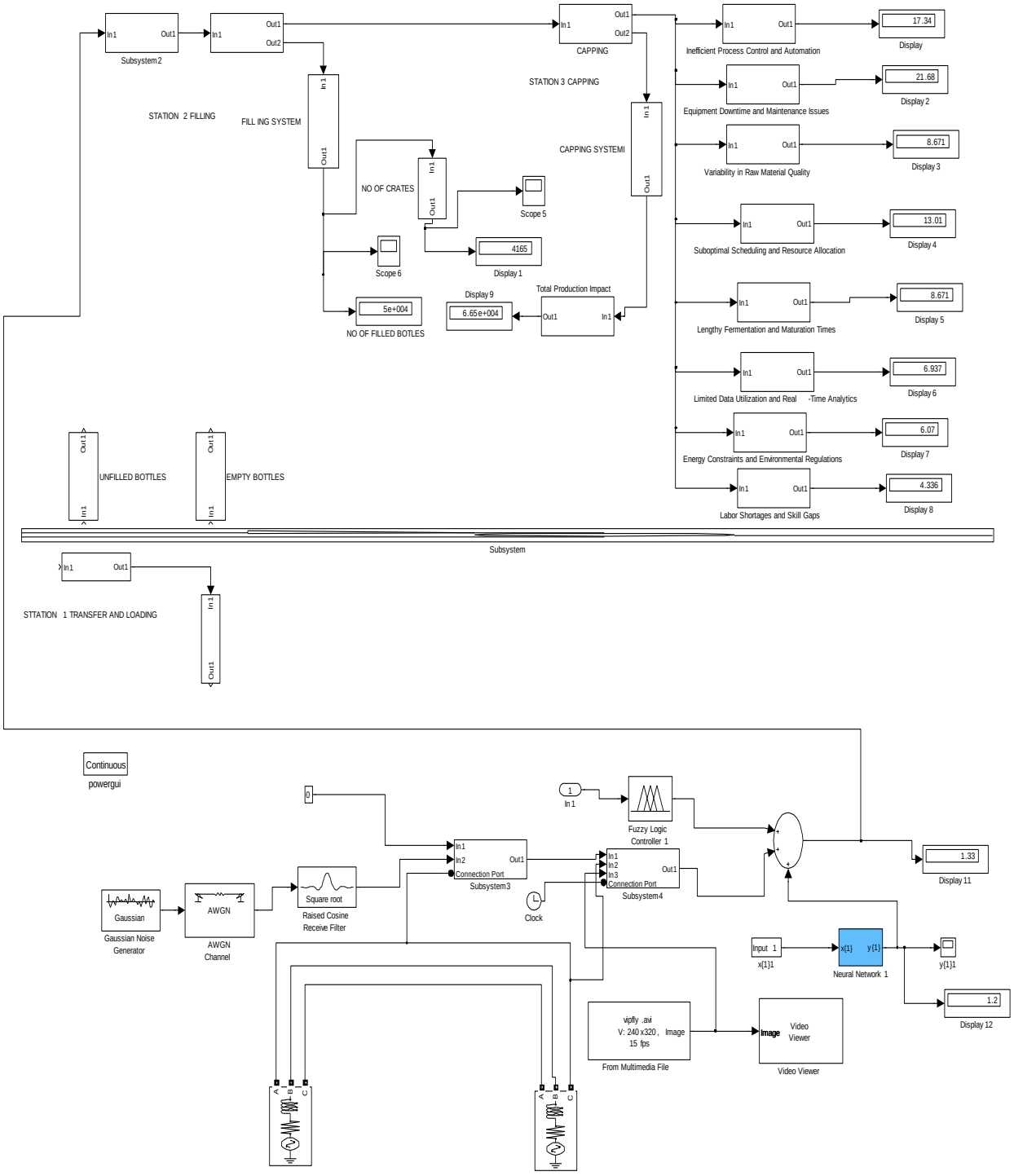
To design a SIMULINK model for leverage machine learning



To develop an algorithm that will implement the process

1. Characterize and establish the causes of poor production capacity in the brewery industry.
2. Identify inefficient Process Control and Automation
3. Identify Equipment Downtime and Maintenance Issues
4. Identify Variability in Raw Material Quality
5. Identify Suboptimal Scheduling and Resource Allocation
6. Identify Lengthy Fermentation and Maturation Times
7. Identify Limited Data Utilization and Real-Time Analytics
8. Identify Energy Constraints and Environmental Regulations
9. Identify Labor Shortages and Skill Gaps
10. Identify Total Production Impact
11. Design a conventional SIMULINK model for production processes in the brewery industry and integrate 2 through 10
12. Design leverage machine learning rule base that will reduce the causes of poor production capacity in a brewery industry and simultaneously increase the production capacity.
13. Train ANN in the designed machine learning rule base for effective reduction of the causes of poor production capacity in the brewery industry and simultaneously increase the production capacity
14. Design a SIMULINK model to leverage machine learning
15. Integrate 12 through 14
16. Integrate 15 in 11
17. Do the causes of poor production capacity in a brewery industry reduce?
18. IF NO go to 16
19. IF YES go to 23
20. Does the production capacity in a brewery industry improve?
21. IF NO go to16
22. IF YES go to 23
23. Optimized production processes and capacity in the brewery industry.
24. Stop
25. END

To design a SIMULINK model for leveraging machine learning to optimize production processes and capacity in the brewery industry.



To validate and justify the percentage improvement in the production capacity of a brewery industry with and without leveraging machine learning

To find a percentage improvement in the reduction of inefficient Process Control and Automation cause of poor production capacity in the brewery industry by leveraging machine learning

Conventional inefficient Process Control and Automation =20%

Leveraging machine learning inefficient Process Control and Automation =17.34%

%improvement in the reduction of inefficient Process Control and Automation caused by poor production capacity in the brewery industry by leveraging machine learning

Conventional inefficient Process Control and Automation - Leveraging machine learning inefficient Process Control and Automation %improvement in the reduction of inefficient Process Control and Automation caused by poor production capacity in the brewery industry by leveraging machine learning =20% - 17.34% %improvement in the reduction of inefficient Process Control and Automation caused by poor production capacity in the brewery industry by leveraging machine learning=2.66%

To find a percentage improvement in the reduction of Lengthy Fermentation and Maturation Times caused by poor production capacity in the brewery industry by leveraging machine learning.

Conventional Lengthy Fermentation and Maturation Times =10%

Leveraging machine learning Lengthy Fermentation and Maturation Times =8.7%

%improvement in the reduction of Lengthy Fermentation and Maturation Times caused by poor production capacity in the brewery industry by leveraging machine learning

Conventional Lengthy Fermentation and Maturation Times - Leveraging machine learning Lengthy Fermentation and Maturation Times %improvement in the reduction of Lengthy Fermentation and Maturation Times caused by poor production capacity in the brewery industry by leveraging machine learning =10% - 8.7% %improvement in the reduction of Lengthy Fermentation and Maturation Times caused by poor production capacity in the brewery industry by leveraging machine learning =1.3%

To find a percentage improvement in the production capacity in the brewery industry by leveraging machine learning Conventional production capacity =50,000bottles

Leveraging machine learning production capacity =6, 6500bottles

%improvement in the production capacity in the brewery industry by leveraging machine learning =

$$\frac{\text{Leveraging machine learning production capacity - Conventional production capacity}}{\text{Conventional production capacity}} \times 100\% \quad 1$$

%improvement in the production capacity in the brewery industry by leveraging machine learning =

$$\frac{6,\ 6500\text{bottles} - 50{,}000\text{bottles}}{50{,}000\text{bottles}} \times 100\% \quad 1$$

%improvement in the production capacity in the brewery industry by leveraging machine learning=33%

3.0 Results and Discussions

Table 3 Comparison of conventional and leveraging machine learning inefficient Process Control and Automation cause of poor production capacity in the brewery industry

Time (days)	Conventional inefficient Process Control and Automation cause poor production capacity in the brewery industry (%)	Leveraging machine learning inefficient Process Control and Automation causes poor production capacity in the brewery industry (%)
1	20	17.34
2	20	17.34
3	20	17.34
4	20	17.34
10	20	17.34

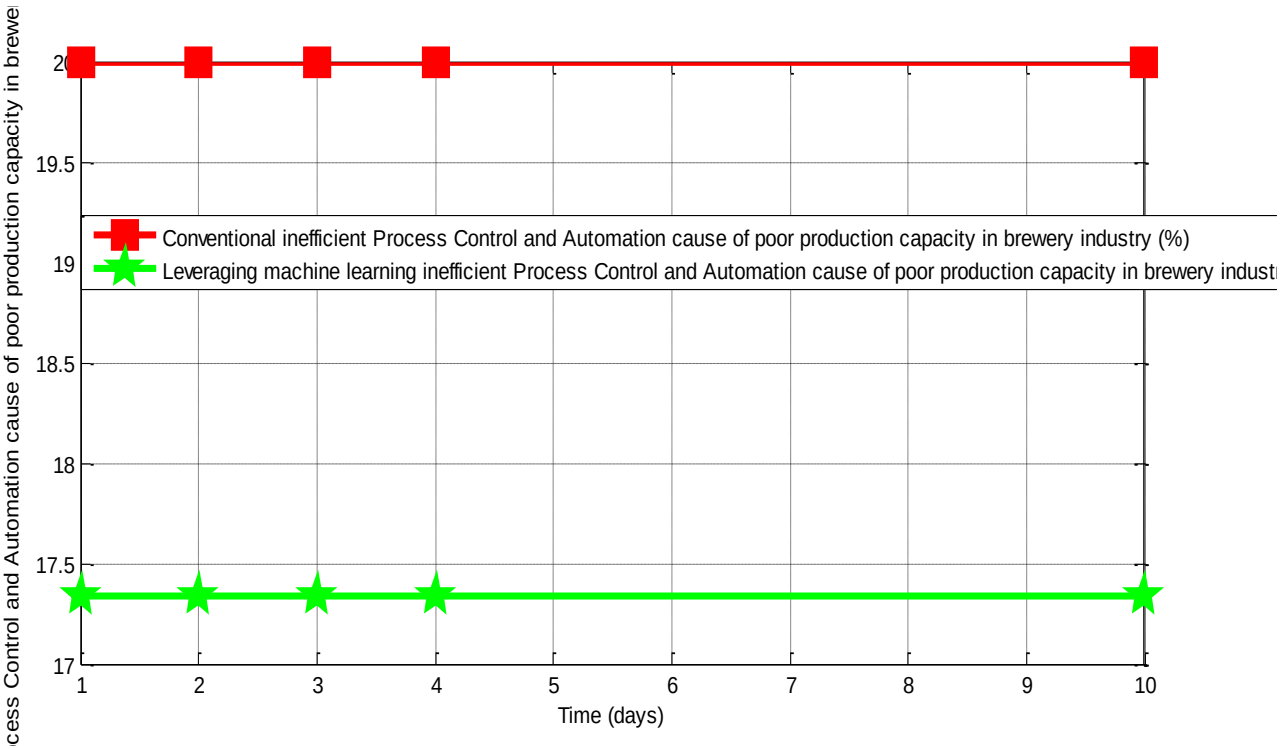


Fig 7 Comparison of conventional and leveraging machine learning inefficient Process Control and Automation cause of poor production capacity in the brewery industry

The conventional inefficient Process Control and Automation cause of poor production capacity in the brewery industry was 20%. On the other hand, when leveraging machine learning was introduced in the system, it drastically reduced inefficient Process Control and Automation causing poor production capacity in the brewery industry to 17.34% thereby enhancing the production capacity.

Table 4 Comparison of conventional and leveraging machine learning Lengthy Fermentation and Maturation Times cause poor production capacity in the brewery industry

Time (days)	Conventional Lengthy Fermentation and Maturation Times Cause of poor production capacity in the brewery industry (%)	Leveraging Machine Learning Lengthy Fermentation and Maturation Times Cause of Poor Production Capacity in the Brewery Industry (%)
1	10	8.7
2	10	8.7
3	10	8.7
4	10	8.7
10	10	8.7

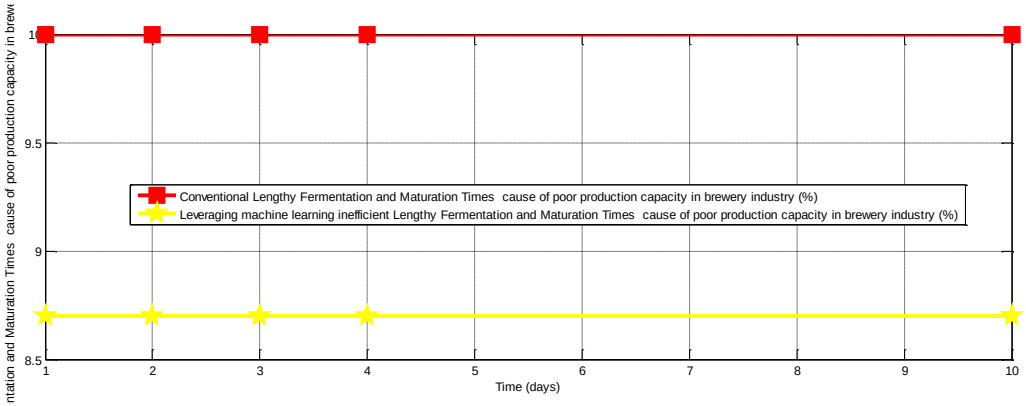


Fig 8 Comparison of conventional and leveraging machine learning. Lengthy Fermentation and Maturation Times cause poor production capacity in the brewery industry.

The conventional Lengthy Fermentation and Maturation Times cause poor production capacity in the brewery industry by 10%. Meanwhile, when machine learning was incorporated into the system, it decisively reduced Lengthy Fermentation and Maturation Times, causing poor production capacity in the brewery industry to 8.7%.

Table 5 Comparison of conventional and leveraging machine learning production capacity in the brewery industry

Time (days)	Conventional production capacity in the brewery industry (bottles)	Leveraging machine learning production capacity in the brewery industry (bottles)
1	50000	6 6500
2	50000	6 6,500
3	50000	6 6,500
4	50000	6 6,500
10	50000	6 6,500

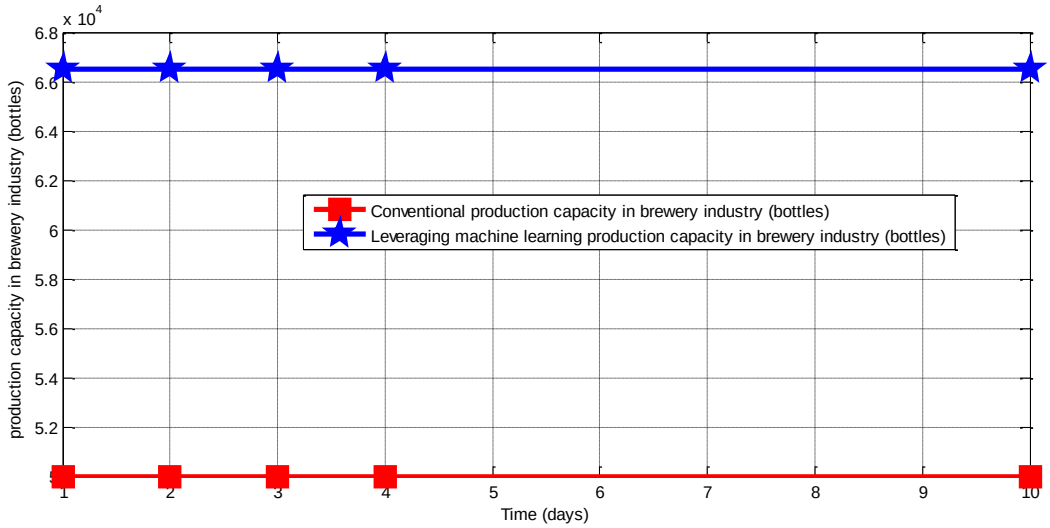


Fig 9 Comparison of conventional and leveraging machine learning production capacity in the brewery industry.

The conventional production capacity in the brewery industry was 50000 bottles of drink. On the other hand, when leveraging machine learning was inculcated in the system, it simultaneously enhanced the production capacity in the brewery industry to 6500 bottles of drink. Finally, with these results obtained, it showed that production capacity in the brewery industry was optimized by 33%.

4.0 Conclusion

The consistent poor production capacity experienced in the brewery industry is anchored on these factors, inefficient Process Control and Automation, Equipment Downtime and Maintenance Issues, Variability in Raw Material Quality, Suboptimal Scheduling and Resource Allocation, Lengthy Fermentation and Maturation Times, Limited Data Utilization and Real-Time Analytics, Energy Constraints and Environmental Regulations, Labor Shortages and Skill Gaps coupled with Total Production Impact. This was overcame by introducing leveraging machine learning to optimize production processes and capacity in the brewery industry, to perfectly achieve this, it was done in the approach, characterizing and establishing the causes of poor production capacity in a brewery industry, designing a conventional SIMULINK model for production processes in the brewery industry, designing leverage machine learning rule base that will reduce the causes of poor production capacity in a brewery industry and simultaneously increase the production capacity, training ANN in the designed machine learning rule base for effective reduction of the causes of poor production capacity in a brewery industry and simultaneously increase the production capacity, designing a SIMULINK model for leverage machine learning, developing an algorithm that will implement the process, designing a SIMULINK model for leveraging machine learning to optimize production processes and capacity in the brewery industry and validating and justifying the percentage improvement in the production capacity of a brewery industry with and without leveraging machine learning. The results obtained were the conventional inefficient Process Control and Automation cause of poor production capacity in the brewery industry was20%. On the other hand, when leveraging machine learning was introduced in the system, it drastically reduced inefficient Process Control and Automation caused poor production capacity in the brewery industry to17.34% thereby enhancing the production capacity, the conventional Lengthy Fermentation and Maturation Times caused poor production capacity in brewery industry was10%. Meanwhile, when leveraging machine learning was incorporated into the system, it decisively reduced Lengthy Fermentation

and Maturation Times caused by poor production capacity in the brewery industry to 8.7% and the conventional production capacity in the brewery industry was 50000 bottles of drink. On the other hand, when leveraging machine learning was inculcated in the system, it simultaneously enhanced the production capacity in the brewery industry to 6500 bottles of drink. Finally, with these results obtained, it showed that production capacity in the brewery industry was optimized by 33%.

Low production capacity in the brewery industry can stem from various factors, often interrelated and influenced by production dynamics, resource availability, and operational inefficiencies. Here are some common causes:

1. Inefficient Process Control and Automation

- Many breweries still rely on traditional process control methods, which lack the flexibility to adapt quickly to changing conditions or demand fluctuations. Inadequate automation can lead to bottlenecks, especially in stages like fermentation, packaging, or bottling, where delays reduce overall capacity (Rathore & Tiwari, 2020).

2. Equipment Downtime and Maintenance Issues

- Frequent breakdowns or maintenance issues with key machinery can significantly disrupt production schedules, leading to reduced capacity. Predictive maintenance, often enabled by machine learning, is not widely implemented in some breweries, leading to unexpected downtimes and costly repairs (Agrawal et al., 2020).

3. Variability in Raw Material Quality

- The quality and consistency of ingredients, particularly grains, hops, and yeast, impact the efficiency of brewing processes. Variability in raw material quality can cause fluctuations in fermentation times and final product quality, necessitating adjustments that reduce production capacity (Oliveira & Cunha, 2019).

4. Suboptimal Scheduling and Resource Allocation

- Poor scheduling and resource allocation can lead to inefficient use of labor, equipment, and materials. Without optimal scheduling, breweries may struggle to balance production demands, often resulting in overworked machines or underutilized equipment (Wuest et al., 2019).

5. Lengthy Fermentation and Maturation Times

- Beer production includes phases such as fermentation and maturation, which require specific timeframes for quality consistency. If these processes are extended due to inefficiencies or process deviations, production capacity is constrained (Lydon et al., 2021).

6. Limited Data Utilization and Real-Time Analytics

- A lack of real-time data analytics and process insights can prevent breweries from making immediate adjustments during production. This limits the ability to optimize processes on the go, leading to production inefficiencies and lower overall capacity (Singh & Kumar, 2021).

7. Energy Constraints and Environmental Regulations

- Energy usage in brewing is significant, especially in heating, cooling, and refrigeration stages. Energy limitations or high costs can lead to intentional scaling down of production to stay within budget, reducing capacity (Zhou et al., 2021).

8. Labor Shortages and Skill Gaps

- A shortage of skilled workers or high turnover rates can lead to production delays and errors. Skilled personnel are often required to manage complex brewing operations, and a lack of experience can reduce production efficiency and capacity (Bishop & Hines, 2020).

By addressing these challenges—often through automation, predictive analytics, and better resource management—breweries can optimize production capacity and enhance their ability to meet demand while ensuring quality and efficiency.

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