Journal of Statistics & Management Systems
ISSN 0972-0510 (Print), ISSN 2169-0014 (Online)
Vol. 26 (2023), No. 5, pp. 1161–1174
DOI : 10.47974/JSMS-1169

An empirical study to predict churn of online multiplayer games and its impact on revenue of the game developing company

Krishna Kumar Singh *
Symbiosis Centre for Information Technology
Symbiosis University
Pune
Maharashtra
India

Sachin Rohatgi †
Amity Global Business School
Amity University
Noida
Uttar Pradesh
India

M. P. Singh §
Graphic Era (Deemed to be University)
Dehradun
Uttarakhand
India

Abstract

Online multiplayer games are becoming massively popular nowadays. However, the churn of the players is becoming a significant concern as it is challenging to predict whether a player will churn or not, impacting business revenue. In this research, authors tried to solve this problem by predicting the player churn in advance using predictive analytics, thereby enabling the business owners to undertake steps to prevent player churn resulting in revenue stability. To achieve this, the authors collected the data from online and gaming platforms and then applied various pre-processing steps such as data conversion to make data suitable to use and then tested and applied a machine learning-based model for prediction by selecting churn period as the threshold value. Finally, various classifiers, such

*E-mail: krishnakumar@scit.edu (Corresponding Author)
† E-mail: skrohatgi@amity.edu
§ E-mail: dmps96@gmail.com

as logistic regression, were applied to predict whether a player will churn. The results were very satisfactory, as predicting churn with perfect accuracy was possible. The decision tree provides the best results, which were proximately 99.1 %, and other algorithms like logistic regression, random forest, and Adaboost gave predictive results of 96.86 %, 95.47 %, and 98.8 %, respectively. The accuracy of all the models has also been summarised. Hence, by making predictions in advance, the online platforms will take preventive measures to minimize the churn of players and increase revenue accordingly.

Subject Classification: *H27, C70.*

Keywords: *Online multiplayer games, Churn prediction, Machine learning, Big data.*

Introduction

Online multiplayer games are video games that allow multiple players to compete or collaborate with one another over the internet. These games can be played on a variety of platforms, including personal computers, gaming consoles, and mobile devices. In online multiplayer games, players from different parts of the world can join in a virtual world and interact with each other in real-time. Players can communicate with each other through text or voice chat and work together to achieve a common goal or compete against each other to see who can achieve the highest score or win the game. Online multiplayer games can range from simple, casual games like card games or puzzle games to complex, immersive role-playing games or first-person shooter games. They have become increasingly popular in recent years, as internet connectivity has become more widespread and game developers have focused on creating engaging and social multiplayer experiences. Overall, online multiplayer games provide a unique and exciting way for players to connect with each other and experience the thrill of competition and collaboration in a virtual environment. Churn prediction is the process of using statistical analysis and machine learning algorithms to identify customers who are likely to stop using a product or service. Churn is a term used to describe the rate at which customers leave or discontinue using a product or service over a given period. Churn prediction is commonly used in business, especially in industries with subscription-based or recurring revenue models, such as telecommunications, software as a service (SaaS), and e-commerce. By identifying customers who are at risk of churning, companies can take proactive steps to retain those customers, such as offering special promotions or improving customer service. To predict churn, companies typically analyse customer data such as usage patterns, demographic

information, and customer behaviour. Machine learning algorithms can then be used to identify patterns and correlations in the data that are indicative of customers who are likely to churn. Churn prediction can be a valuable tool for businesses, as it can help them to reduce customer attrition rates and increase customer retention, which can ultimately lead to increased revenue and profitability. Machine learning is a field of computer science and artificial intelligence that focuses on developing algorithms and models that enable computers to learn from data and make predictions or decisions without being explicitly programmed. In other words, it is a subset of artificial intelligence that uses statistical techniques to enable machines to improve their performance on a specific task over time, based on the data they are fed. In machine learning, computers are trained to learn from examples, which are called training data. This training data is used to create a model that can then be used to make predictions or decisions on new, unseen data. The process of training a machine learning model involves selecting the appropriate algorithm, defining the problem or task, preparing and cleaning the data, selecting relevant features, and optimizing the model parameters. Over the past few years, with the advent of high-speed Wi-Fi and LTE connectivity, the adoption of online games and hence the number of multiplayer gamers has significantly increased. Multiplayer online games such as grand theft online and overwatch are immensely popular, especially among the young population. However, it is due to this craze only the number of these games has increased drastically over the recent years. As a result, players now have wider choices available most of which hold a strong position. So, they have the tendency to make switches from one game to another, mostly permanently leading to churn. Most of these churns are highly unpredictable with general analysis without any specified reason by the player. Also, the number of possible reasons to make such switches is large, making churn prediction even tougher. However, for a developer and publisher of a specific game to continually make money, predicting churn and taking necessary actions accordingly is highly important; otherwise, the player base will continue to degrade. To solve this issue, this paper presents a possible solution for predicting player churn. Thanks to advancements in the field of computer hardware and machine learning, this analysis was made possible. Here, the researchers have taken one of the popular games, World of Warcraft, which has an extensive user base and collected data of it. They have then performed some required pre-processing steps along with certain assumptions for churn, and after applying some popular ML techniques such as logistic

regression and Ada-boost, they were able to achieve very high levels of accuracy. Thus, their methodology provides a simple yet effective way of predicting churn, thus enabling necessary preventive actions to maintain most of the user base without much sacrifice.

Literature review

In one of the related papers, there is use of survival ensembles to forecast game abandonment. The strategy accurately predicts both the level at which each player will exit the game and the amount of time they have spent playing up to that point. It's also resistant to a variety of data distributions and adaptable to a large range of response variables, all while allowing for effective parallelization. This makes the methodology ideal for churner analysis in real time, even for games with millions of daily active users [2]. The authors of another research focused on new players and utilised observation period (OP) and churn prediction period to explicitly define churn (CP). They created a standard churn analysis technique for casual games based on the concept. They covered topics like raw data pre-processing, feature engineering, and feature analysis, as well as churn prediction modelling with traditional machine learning algorithms (logistic regression, gradient boosting, and random forests) and two deep learning algorithms (CNN and LSTM) and sensitivity analysis for OP and CP. A total of 193,443 unique player records and 10,874,958 play log records were analysed from three separate casual games' play log data. While the results of the analysis are beneficial, the overall findings suggest that a limited number of well-selected features utilised as performance metrics may be adequate for making significant action decisions, and that OP and CP should be correctly chosen based on the analysis purpose [6]. The authors presented a churn prediction approach for optimising profit in the following article, which consists of two primary steps: first, selecting a prediction target, and second, setting the model's threshold. In online games, the distribution of a user's customer lifetime value is skewed, with a few people accounting for the majority of revenues and the majority of churners being free users. As a result, it is more cost-effective to concentrate on predicting attrition among loyal customers who receive sufficient rewards. In addition, it is more lucrative to tweak the prediction model's threshold such that the projected profit is maximised rather than the accuracy. As a result, they tested the suggested technique on a real-world online gaming service, Aion, one of South Korea's most popular online games, and found that our method is

more cost-effective than the prediction model for total users when campaign cost and conversion rate are taken into account [5]. Sachin Rohatgi, et. al in their paper title, Saving Patterns and Investment Preferences: Prediction Through Machine Learning Approaches, provides an overview of big data analytics, including its benefits, challenges, and tools. The study also examines the application of big data analytics in various domains, including healthcare, finance, and transportation [13]. " S. Rohatgi et al, in their paper, Comparative Analysis of Machine Learning Algorithm to Forecast Indian Stock Market, investigates the relationship between big data analytics and firm performance. The study finds that big data analytics has a positive impact on various aspects of firm performance, including operational efficiency, customer satisfaction, and innovation [14]. "Big Data, Artificial Intelligence, and Ethics" by Karim R. Lakhani and Marco Iansiti (2020) discusses the ethical implications of big data and artificial intelligence. The study examines the potential for bias and discrimination in big data analysis and proposes a framework for ethical data use [10]. " K. K. Singh et al, in their paper, green database model for stock market: a case study of Indian stock market, provides an overview of big data visualization techniques and tools. The study examines the effectiveness of different visualization approaches, including interactive and immersive visualization, and identifies key research challenges in this area [7]. Singh, K.K. et al, in this paper title, smart wireless network algorithm in the era of big data, explores the relationship between big data analytics and business value creation. The study identifies the key factors that contribute to the success of big data analytics initiatives, including data quality, analytics capabilities, and organizational culture [15]. Sahera et. al. (2022) provides a comprehensive review of machine learning applications in healthcare. The study examines the use of machine learning for disease diagnosis, drug discovery, and personalized medicine, among other applications, and discusses the challenges associated with implementing machine learning in healthcare [1]. " Brain tumor detection using inpainting and deep ensemble model by Sahoo et. al. (2021) explores the applications of machine learning in cancer prediction and diagnosis. The study identifies the key machine learning models and algorithms that have been used for these applications and evaluates their performance [16]."A review of applications of machine learning in Cancer Prediction and Diagnosis. " by Sharma et. al. (2021) explores the applications of machine learning in cancer prediction and diagnosis. The study identifies the key machine learning models and algorithms that have been used for these applications and evaluates their performance [17]. Overall, these

studies highlight the diverse applications of machine learning in various domains and the need for new techniques and algorithms to address the challenges associated with different applications. They provide valuable insights into the opportunities and challenges associated with machine learning and offer recommendations for future research and practice. Dhangar, Kiran, and Prateek Anand in their paper, A Review on Customer Churn Prediction Using Machine Learning Approach, provides a comprehensive review of customer churn prediction using machine learning. The study examines the different machine learning algorithms and techniques that have been used for churn prediction, as well as the challenges associated with implementing these algorithms in practice [4]. "A Review of Machine Learning Approaches to Customer Churn Prediction" by Lalwani et. al. (2022) explores the use of machine learning for customer churn prediction. The study evaluates the performance of different machine learning algorithms and techniques and identifies the key features that are most important for predicting churn [9]. " P. Gopal and N. B. MohdNawi, "A Survey on Customer Churn Prediction using Machine Learning and data mining Techniques in E-commerce," examines the use of machine learning for churn prediction in e-commerce. The study identifies the different data sources and features that are used for churn prediction, as well as the machine learning algorithms and techniques that have been applied in this context [11]. "Churn Prediction in Subscription Services: A Review of Recent Research" by Shokoufeh Mirzaei et. al. (2020) investigates the use of churn prediction in subscription services. The study evaluates the performance of different machine learning models and techniques and identifies the key factors that contribute to churn in this context [8]. Overall, these studies highlight the importance of churn prediction in various industries and the potential of machine learning techniques for predicting churn. They provide valuable insights into the challenges and opportunities associated with churn prediction and offer recommendations for future research and practice. "A survey on online gaming platforms: Player behaviour, social interactions, and business models" by Hongzhi Yin et. al. (2021) provides a comprehensive review of online gaming platforms. The study examines player behavior, social interactions, and business models in online multiplayer games, and discusses the challenges and opportunities associated with these factors [3]. " Raith L, Bignill J, Stavropoulos V, Millear P, Allen A, Stallman HM, Mason J, De Regt T, Wood A and Kannis-Dymand L (2021) Massively Multiplayer Online Games and Well-Being: A Systematic Literature Review, investigates the social and psychological

aspects of online multiplayer games. The study examines the impact of online gaming on social interaction, emotional well-being, and addiction, and discusses the potential benefits and risks of online gaming [12]. Overall, these studies highlight the importance of online multiplayer games as a social and entertainment platform, and the potential benefits and risks associated with these games. They provide valuable insights into the design, development, and evaluation of online multiplayer games, and offer recommendations for future research and practice.

Research methodology and model

The following research was basically done to estimate churning of players in online video games. For this, selection of an appropriate online game was essential and hence world of warcraft which is a very popular online multiplayer game was considered. The game has huge user base with millions of active users in year 2020. The game is published by Blizzard Entertainment. Now, the next issue was data collection. The researchers went through various datahub bases for this. The data so obtained was not ready for direct analysis, hence, some pre-processing was done to make it fit for the same. The focus was timestamp data which required greater processing. The next decision was to be made on selecting a suitable churn period without losing many customers. By covering greatest possible customers, it was made possible to select appropriate churn period. Then, they created a new column which defined whether a player would churn

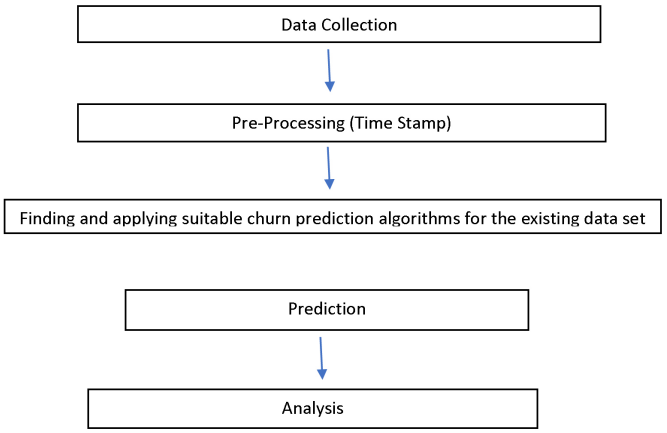

Figure 01

Model for implementation of churn prediction models

or not and hence became the focus of our prediction which is basically binary in nature. They finally used appropriate classification algorithms like logistic regression to make predictions and the one with highest accuracy was chosen for making predictions. Overall, it could be said that processing of data consumed 70% of the effort with remaining for making predictions.

Figure 01, explained how authors implemented model. First step is to collect data and next did pre-Processing based upon time stamp. Next step is finding and applying suitable churn prediction algorithms for the existing data set and next authors did prediction as well as analysis of predictive results. To successfully execute the research, the researchers first collected the data from a reliable source, GitHub. The data was a big data consisting of 10826734 rows and 7 columns out of which three were numeric, three were categorical and one was time data.

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 10826734 entries, 0 to 10826733
Data columns (total 7 columns):
 #   Column     Dtype
---  ------     -----
 0   char       int64
 1   level      int64
 2   race       object
 3   charclass  object
 4   zone       object
 5   guild      int64
 6   timestamp  object
dtypes: int64(3), object(4)
memory usage: 578.2+ MB
```

Each player was uniquely defined by his/her character number. Each one of them had levels achieved as per time of collection followed by race, character class and zone. The time stamp for each player consisted of date and time.

	char	level	race	charclass	zone	guild	timestamp
0	59425	1	Orc	Rogue	Orgrimmar	165	01/01/08 00:02:04
1	65494	9	Orc	Hunter	Durotar	-1	01/01/08 00:02:04
2	65325	14	Orc	Warrior	Ghostlands	-1	01/01/08 00:02:04

First, the data was checked for any missing values which was found to be none.

```
char          0
 level        0
 race         0
 charclass    0
 zone         0
 guild        0
 timestamp    0
dtype: int64
```

The categorical columns were nominal in nature. Hence, instead of directly converting them into numerical values, each category of a column

was formed into different columns and hence were converted into binary type with an example shown below.

	char	level	charclass	zone	guild	timestamp	race_Blood Elf	race_Orc	race_Tauren	race_Troll	race_Undead
0	59425	1	Rogue	Orgrimmar	165	01/01/08 00:02:04	0	1	0	0	0
1	65494	9	Hunter	Durotar	-1	01/01/08 00:02:04	0	1	0	0	0

It was found that the players were repeated in the data multiple times due to their multiple logins. Hence, by using groupby function, these players were brought to single row for each one of them and accordingly a new data set was created.

	guild	total_timestamps	unique_days	max_level	min_month	max_month	a	b	c	d	...	p1	p2	p3	p4	p5	p6	p7	p8	p9	q1
0	6	1	1	18	12	12	0.0	1.0	0.0	0.0	...	0.0	0	0	0	0	0	0.0	0.0	0	0
1	282	655	50	71	1	12	0.0	655.0	0.0	0.0	...	0.0	40	0	0	0	23	22.0	0.0	0	0
2	79	2739	133	70	1	6	0.0	2739.0	0.0	0.0	...	125.0	7	0	2	0	21	57.0	0.0	15	1
3	-1	674	49	61	7	11	0.0	674.0	0.0	0.0	...	0.0	15	0	1	0	12	1.0	0.0	9	0
4	366	3001	149	70	1	12	0.0	3001.0	0.0	0.0	...	313.0	0	0	0	0	0	76.0	0.0	0	0
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
37349	-1	5	1	5	12	12	5.0	0.0	0.0	0.0	...	0.0	0	0	0	0	0	0.0	0.0	0	0
37350	-1	3	1	3	12	12	3.0	0.0	0.0	0.0	...	0.0	0	0	0	0	0	0.0	0.0	0	0
37351	-1	1	1	1	12	12	1.0	0.0	0.0	0.0	...	0.0	0	0	0	0	0	0.0	0.0	0	0
37352	-1	1	1	1	12	12	0.0	1.0	0.0	0.0	...	0.0	0	0	0	0	0	0.0	0.0	0	0
37353	-1	1	1	1	12	12	0.0	0.0	1.0	0.0	...	0.0	0	0	0	0	0	0.0	0.0	0	0

37354 rows × 177 columns

Now, the next focus was the processing of timestamp column. Using a customised time transform function, first the data was split into two columns of time and date. The date part was further split into month, day and weekday and accordingly a new data was created. The focus however was month data.

	date	time	Month	Day	Weekday
	01/01/2008	00:00	1	1	1
	01/01/2008	00:00	1	1	1
	01/01/2008	00:00	1	1	1

Further, max guild for each player was found using max function along with max level, total timestamp values, number of unique days (By using unique function). Also, for each player maximum and minimum month was calculated by using max and min functions. All these calculations were ultimately added to form a new dataset.

total_timestamps	unique_days	max_level	min_month	max_month
1	1	18	12	12
655	50	71	1	12
2739	133	70	1	6
674	49	61	7	11
3001	149	70	1	12

The next task was to determine the appropriate churn period. To do this, the researchers calculated the difference between maximum and minimum months and then sorted the values in ascending order.

```
0          1
24401      1
24400      1
24399      1
24398      1
           ..
10037     12
6155      12
3283      12
5945      12
4386      12
```

Then, they calculated the number of players for different difference values by using appropriate programming and then finally came to the conclusion of using 10 months difference as the appropriate churn period as it covered almost 90% of the players which satisfied our requirements. Setting this as a criterion, a new column was created which defined whether the player will churn or not.

```
0        0
1        1
2        0
3        0
4        1
        ..
37349    0
37350    0
37351    0
37352    0
37353    0
Name: Playing_after_10_months, Length: 37354, dtype: int64
```

The final step was making prediction. As the target variable was binary in nature, hence, appropriate classification algorithms were used. First, decision tree with repeated stratified K fold method was used. Then, they applied logistic regression after doing standard scaling and PCA followed by random forest and Ada boost.

Results

After applying decision tree classifier together with repeated K fold stratified method, the accuracy was found to be 100%.

```
print('Accuracy: %.3f (%.3f)' % (mean(n_scores), std(n_scores)))
```

```
Accuracy: 1.000 (0.000)
```

After performing standard scaling and PCA and then applying logistic regression, the accuracy was found out to be 96.86%.

```
print(accuracy_score(y_test, predictions_test))
```

```
0.9686055001216841
```

After performing standard scaling and applying K fold method and then applying random forest classifier, the accuracy was found to be 95.47%.

```
seed = 7
num_trees = 100
max_features = 3
kfold = model_selection.KFold(n_splits=10, random_state=seed, shuffle=True)
model = RandomForestClassifier(n_estimators=num_trees, max_features=max_featur
results = model_selection.cross_val_score(model, X, Y, cv=kfold)
print("Accuracy on test dataset is {}".format(results.mean()))
```

```
Accuracy on test dataset is 0.9547039191741987
```

In case of Ada Boost classifier together with K fold selection method, accuracy was found to be 100%.

```
seed = 7
num_trees = 30
kfold = model_selection.KFold(n_splits=10, random_state=seed, shuffle=True)
model = AdaBoostClassifier(n_estimators=num_trees, random_state=seed)
results = model_selection.cross_val_score(model, X, Y, cv=kfold)
print("Accuracy on test dataset is {}".format(results.mean()))
```

```
Accuracy on test dataset is 1.0
```

Thus, the models along with accuracy is summarised below.

Sn	Model	Accuracy
1	Decision Tree	100%
2	Logistic Regression	96.86%
3	Random Forest	95.47%
4	Ada Boost	100%

Conclusion

By this analysis, it is hence found that it is possible to determine whether a player will churn or not by going through his/her historical playtime record. Here, the researchers had selected 10 months churn

period as the most suitable ones and by applying suitable machine learning algorithm they were able to make predictions with very good accuracy levels. It is to be noted that the highest accuracy was achieved in case of decision tree and Ada Boost learning models followed by others. By knowing that whether a player will churn or not, it will be possible for game publishers to apply appropriate marketing strategies targeting the players who are likely to churn for greater retention and hence maintain upward growth of player base. Making early predictions will also enable the developers to create new features or make changes accordingly that will not help in not only making new customers but also retaining existing ones. Some possible future works may include, A three-year time period can be included for even more accurate analysis with extended churn prediction and different playing patterns can be analysed by studying the performance of different algorithms on the players.

References

[1] Sahera Hussein Zain Al-Thalabi, Ali Akbar Heydari & Masoud Tavakoli. Modeling and prediction using an artificial neural network to study the impact of foreign direct investment on the growth rate / a case study of the State of Qatar, *Journal of Statistics and Management Systems*, 25:8, 1991-2003 (2022), DOI: 10.1080/09720510.2022.2060914.

[2] Bertens, P., Guitart, A., & Periáñez, Á., Games and big data: A scalable multi-dimensional churn prediction model. In 2017 IEEE conference on computational intelligence and games (CIG), pp. 33-36. IEEE (2017, August).

[3] Chang, W.-L., Chen, L.-M. and Hsieh, Y.-H., "Online to offline social interaction on gaming motivations", Kybernetes, Vol. 51 No. 12, pp. 3508-3525 (2022). https://doi.org/10.1108/K-02-2021-0156.

[4] Dhangar, Kiran, and Prateek Anand. "A Review on Customer Churn Prediction Using Machine Learning Approach." *International Journal of Innovations in Engineering Research and Technology*, vol. 8, no. 05, pp. 193-201 (2021), doi:10.17605/OSF.IO/ACNKJ.

[5] Jeon, J., Yoon, D., Yang, S., & Kim, K. Extracting gamers' cognitive psychological features and improving performance of churn prediction from mobile games. In 2017 IEEE Conference on Computational Intelligence and Games (CIG), pp. 150-153, IEEE (2017, August).

[6] Kim, S., Choi, D., Lee, E., & Rhee, W., Churn prediction of mobile and online casual games using play log data. PloS one, 12(7), e0180735 (2017).

[7] K. K. Singh, P. Dimri and M. Rawat, "Green database model for stock market: a case study of Indian stock market," 2014 5th International Conference - Confluence The Next Generation Information Technology Summit (Confluence), Noida, India, pp. 848-853 (2014), doi: 10.1109/CONFLUENCE.2014.6949306.

[8] Kristof Coussement, Dirk Van den Poel, Churn prediction in subscription services: An application of support vector machines while comparing two parameter-selection techniques, Expert Systems with Applications, Volume 34, Issue 1, Pages 313-327 (2008),

[9] Lalwani, P., Mishra, M.K., Chadha, J.S. et. al. Customer churn prediction system: a machine learning approach. Computing 104, 271–294 (2022). https://doi.org/10.1007/s00607-021-00908-y.

[10] Leavy, B., "Marco Iansiti and Karim Lakhani: strategies for the new breed of "AI first" organizations", Strategy & Leadership, Vol. 48 No. 3, pp. 11-18 (2020). https://doi.org/10.1108/SL-02-2020-0026.

[11] P. Gopal and N. B. MohdNawi, "A Survey on Customer Churn Prediction using Machine Learning and data mining Techniques in E-commerce," 2021 IEEE Asia-Pacific Conference on Computer Science and Data Engineering (CSDE), Brisbane, Australia, pp. 1-8 (2021), doi: 10.1109/CSDE53843.2021.9718460.

[12] Raith L, Bignill J, Stavropoulos V, Millear P, Allen A, Stallman HM, Mason J, De Regt T, Wood A and Kannis-Dymand L. Massively Multiplayer Online Games and Well-Being: A Systematic Literature Review. Front. Psychol. 12:698799 (2021). doi: 10.3389/fpsyg.2021.698799.

[13] Sachin Rohatgi, P. C. Kavidayal, Krishna Kumar Singh, "Saving Patterns and Investment Preferences: Prediction Through Machine Learning Approaches", Applications of Artificial Intelligence and Machine Learning, vol.925, pp.61 (2022).

[14] S. Rohatgi, K. Kumar Singh and D. Jasuja, "Comparative Analysis of Machine Learning Algorithm to Forecast Indian Stock Market," 2021 International Conference on Advance Computing and Innovative Technologies in Engineering (ICACITE), Greater Noida, India, pp. 278-283 (2021), doi: 10.1109/ICACITE51222.2021.9404642.

[15] Singh, K.K., Kushwaha, V. Smart Wireless Network Algorithm in the Era of Big Data. In: Goyal, D., Gupta, A.K., Piuri, V., Ganzha, M., Paprzycki, M. (eds) Proceedings of the Second International Conference on Information Management and Machine Intelligence. Lecture Notes in Networks and Systems, vol 166. Springer, Singapore (2021).

[16] Debendra Kumar Sahoo, Abhishek Das, Mihir Narayan Mohanty & Satyasis Mishra. Brain tumor detection using inpainting and deep ensemble model, *Journal of Information and Optimization Sciences*, 43:8, 1925-1933 (2022), DOI: 10.1080/02522667.2022.2091094.

[17] Sharma, A., Rani, R. A Systematic Review of Applications of Machine Learning in Cancer Prediction and Diagnosis. Arch Computat Methods Eng 28, 4875–4896 (2021).