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# Machine Learning Based Assessment and Predictive Analysis of In-Vitro Fertilization Success Rate

Vaishali Mehta[1] , Monika Mangla[2] *, Nonita Sharma[3], Manik Rakhra[4] , Tanupriya Choudhury[5] and Garigipati Rama Krishna[6]

[1] CSE Department, Maharishi Markandeshwar University, Ambala, India
[2] Dwarkadas J Sanghvi College of Engineering, Mumbai, India
[3] Indira Gandhi Delhi Technical University for Women, New Delhi, India
[4] School of CSE, Lovely Professional University, Phagwara, Punjab, India
[5]CSE Dept., Graphic Era University, Dehradun, India
[6]Department of Computer Science and Engineering, Koneru Lakshmaiah Education Foundation, Vaddeswaram, Guntur Dist., Andhra Pradesh - 522302, India

## Abstract

INTRODUCTION: The transformation in the lifestyle and other societal and economic factors during modern times have led to rise in the cases of infertility among young generation. Apart from these factors infertility may also be attributed to different medical conditions among both men and women. This rise in the cases of infertility is a matter of huge concern to the mankind and should be seriously pondered upon. However, the unprecedented advancements in the field of healthcare have led to In Vitro fertilization as a rescue to this devastating condition. Although the In Vitro fertilization has the potential to unfurl the happiness, it has associated challenges also in terms of physical and emotional health. Also, the success rate of In Vitro fertilization may vary from person to person.
OBJECTIVES: To predict the success rate of In Vitro fertilization.
METHODS: Machine Learning Models.
RESULTS: It has been observed that Adaboost outperforms all other machine learning models by yielding an accuracy of 97.5%.
CONCLUSION: During the result analysis, it is concluded that if age > 36, there is a negative propensity for clinical pregnancy and if age >40, the probability of a clinical pregnancy dramatically declines. Further, the propensity of clinical pregnancy is positively correlated to the count of embryos transferred in the same IVF cycle.

**Keywords:** In Vitro Fertilization, Machine Learning, Classification, Feature selection, Regression

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## 1. Introduction

During modern times, there has been a significant transformation in the lifestyle. This change in facet of lifestyle may be attributed to various factors namely technological revolutions, urbanization, financial growth, professional career consciousness and many more. While all these factors have escalated the lifestyle of mankind making it more physically relaxed and comfortable. Although it has got a striking change in comparison to elemental lifestyle, it has some challenges and issues also. Basically, this change in lifestyle has caused change in food habits, sedentary lifestyle, and sleep deprivation etc. which is causing adverse effect on the human health.

It has been well established that sedentary lifestyle causes several health issues namely blood pressure, diabetes, and thyroid etc. Among several challenges, the prime concern is the rise in issues related to hormonal imbalance that causes infertility. This rise is owing to

* Corresponding Author. Email: manglamona@gmail.com

modernization of lifestyle leading to sedentary work culture. For instance, as per the authors in [1], it has been well established that physical inactivity in women is closely and positively associated with infertility. As per the report by World Health Organization (WHO) published in April 2023 [2], around 17.5% adult couples have been experiencing infertility. Also, this report clearly mentions that infertility does not discriminate and hence the statistic of infertility is same across all geographical regions. For high-income countries, this ratio of infertility is 17.8% while for middle- and low-income countries, this ratio is 16.5%. These statistics clearly indicate this issue of infertility is a matter of great concern across and globe and hence must be thoughtfully looked upon. Infertility can be technically defined as a disease of reproductive system in women and men that prevents achieving pregnancy even after a year of regular and unprotected sexual intercourse which may further cause deterioration of people's mention, emotional, and psychological health.

While this modernization of lifestyle has caused few challenges, it has also favoured the mankind like never before. The favours to mankind have been in form of advancement in agriculture, education, and healthcare etc. The unprecedented advancement in the domain of healthcare has provided a helping hand mankind to deal with infertility in form of in vitro fertilization (IVF). The IVF is a strenuous process in terms of physical health, mental health and finance. Also, the success rate of IVF is also not certain. Hence, it will be a great relief if some automated system could be devised for predicting the success rate of IVF. This will prevent couples to go through unnecessary turmoil. Authors in this manuscript have undertaken the project to predict the success rate of IVF. For the same, authors have employed various Machine Learning (ML) Models as ML models have already established its supremacy in related prediction and classification problems.

The manuscript is organized into various sections. The widespread issue of infertility along with its possible causes have been discussed in section 1. Related work is presented in section 2. Section 3 is reserved for presenting the current methodology and obtained results are mentioned in section 4. Conclusion is given in section 5.

In order to increase prediction accuracy, this paper focuses on ML approaches by minimizing the features and choosing the best features. The paper is divided into 5 sections. Section 1 describes introduction of CKD. A brief of literature surveyed to carried out this work is presented in Section 2. Section 3 explains the proposed approach. Sections 4 depicts the simulation results and section 5 concludes the research.

## 2. Literature Review

Although, a number of researchers have worked in this domain, this section dis-cusses the significant findings in the domain. While different authors have employed different methodologies to predict the success of IVF, ML has dominated the entire research. This dominance of ML in this field is owing to its capability to perform efficient and effective prediction. Hence, the authors in this paper primarily discuss the research related to employment of ML for prediction of IVF success rate.

Authors in [3] aim to develop a Random Forest (RF) model and perform its comparative analysis with Logistic Regression (LR) model using data pertaining to 1052 women that was collected from a medical facility. For the same, various performance metrics are used which clearly indicate that RFM outperforms LR model by yielding an AUC of 0.74 in comparison to 0.66 yielded by multivariate LR model. Also, the sensitivity of RFM is 0.84 while that for multivariate LR model is 0.66. Similar to AUC and sensitivity, specificity of RF and multivariate LR model is in favour of RF. Thus, the research concludes that RF outperforms multivariate LR model in terms of success rate prediction for IVF.

Another researcher has been carried out in the related domain by authors in [4] where authors aim to assess the quality of embryos from 2nd day to 3rd day in order to enhance the success rate of implantation. An automated system for assessing the quality of embryos may be quite helpful to medical professional. In order to perform the simulation, thousands of images have been trained using Convolutional Neural Network (CNN) and the obtained results are verified using ML models.

For the same, model suggests the count of embryos that must be transferred. Here, authors propose an artificial intelligence (AI) model that will predict the expected outcome. In order to validate the proposed model, dataset pertaining to 1507 cases are considered. Out of the 1507 records, several records are dropped in view of incompleteness. Authors employed 6 ML models namely LR, support vector machine (SVM), light gradient boosting machine (LightGBM), RF, multilayer perceptron (MLP), and extreme gradient boosting (XGBoost). During the comparative analysis, which is performed in terms of different performance metrics, it is evident that XGBoost outperforms all other models and thus can be widely employed. The results obtained in this paper highly advocate the usage of AI models to predict the outcome of IVF.

Here, the underlying classifier models uses genetic algorithm to select the variables. The experiment carried out in the research work concludes that RF and Decision tree (DT) both give comparable performance and outperforms gradient boost method. Here also the authors established the efficacy of AI and ML pertaining to IVF. The other works carried out by different researchers who have also proved the supremacy of ML models in related domain can be referenced [7-10].

As this section clearly establishes the efficacy of ML models in prediction modelling and hence authors aim to propose a model that uses ML towards pre-diction of IVF prediction in the following section.

## 3. Proposed Methodology

In the current research work, authors aim to demonstrate the efficacy of ML models in predicting the success rate of IVF by employing different ML models. The proposed works in 2 phases namely data pre-processing and prediction. The pictorial representation of proposed methodology is illustrated in Fig. 1 [11].

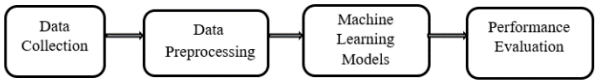


**Figure 1.** Process flow of Proposed Model

### 3.1. Data Collection

During this step, the data is collection so as to perform experimental evaluation. This data may be comprising of various parameters namely age, sperm quality, number of embryos, and number of egg cells etc. that impact the success rate of IVF. In the current research work, authors have collected the dataset from [12] having 333 records.

### 3.2. Data Preprocessing & Filtering

Data collection is followed by data cleaning and data pre-processing so as to remove any outliers that may adversely influence or dominate the result. Also, it handles the missing and duplicate values by replacing them with other values. Also, the non-numeric value is converted to numeric value if any so that ML model can be employed. Further pre-processing also determines the degree of correlation among different input features with output variables which enables the elimination of unnecessary features, also known as principal component analysis. Efficient data processing enhances the efficiency of ML models.

### 3.4. Model Building

Once the data is cleaned and pre-processed, it can be applied with various ML models. Here, authors have employed various machine learning models namely RF, Naïve Bayes (NB), LR, DT, Adaboost, and k nearest neighbour etc.

### 3.4. Performance Evaluation

Further, the efficiency of different machine learning algorithms is compared in order to validate the efficacy of ML models and determine the most optimal ML model. This performance comparison is performed in terms of various performance metrics namely sensitivity, specificity, accuracy, and Area Under Curve (AUC) [13].

## 4. Results and Discussion

For implementation, authors have collected the dataset from [12] with 333 rows having 11 input features. The various features in the dataset are shown in Table 1.

Table 1. Various features of Considered Dataset

| Abbreviation | Available Range | Expected Range |
|---|---|---|
| AGE | 20-50 | 20-40 |
| LOW AFC | 0-40 | >8 |
| MEAN AFC | 0-51.5 | >10 |
| FSH | 0-16 | >3 |
| E2 | 13-100 | >20 |
| MAX E2 | 290-6242 | >1000 |
| MAX DAILY GEN | 100-525 | >200 |
| TOTAL GN | 800-7275 | >3000 |
| OOCYTES | 0-36 | >10 |
| EMBRYOS | 0-20 | >=8 |

The considered dataset has an output variable IVF success that indicates the success of IVF. The data is pre-processed in order to remove any outliers or any less significant attribute. During pre-processing, it is observed that no data is dropped and hence authors have all 333 entries for ML model implementation. The correlation of all input variables to the predictor variable is illustrated in Fig. 2. During the correlation determination, it is clear that long Gn levels has huge significance towards IVF outcomes followed by total frozen and transferred embryos. On the other hand, age and infertility duration have negative influence on the outcome.

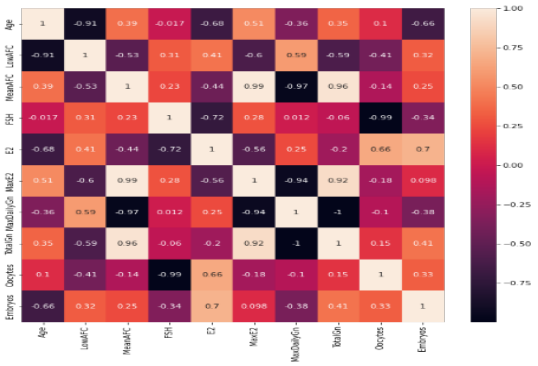


**Figure 2.** Illustration of correlation among various features in the dataset.

In order to carry out the simulation, the dataset is divided training and testing part in ratio of 70:30. The different performance metrics for various ML models are mentioned in Table 2(a) and Table 2(b).

Table 2(a). Comparative Analysis of different ML models

| Classifier | Accuracy | Precision | Recall |
|---|---|---|---|
| RF | 97.5 | 0.89 | 0.95 |
| NB | 87.5 | 0.94 | 0.88 |
| LR | 89 | 0.91 | 0.96 |
| DT | 100 | 1 | 1 |
| AdaBoost | 99.6 | 1 | 1 |
| Knn | 89 | 0.97 | 0.91 |

Table 2(b). Comparative Analysis of different ML models

| Classifier | F1-Score | RMSE | AUC |
|---|---|---|---|
| RF | 0.92 | 0.05 | 1.00 |
| NB | 0.91 | 0.38 | 0.86 |
| LR | 0.93 | 0.32 | 0.75 |
| DT | 1 | 0 | 0.98 |
| AdaBoost | 1 | 0.06 | 0.5 |
| Knn | 0.94 | 0.31 | 0.5 |

The plot of accuracy for different ML models is illustrated in Fig. 3 for enhanced comparative analysis.

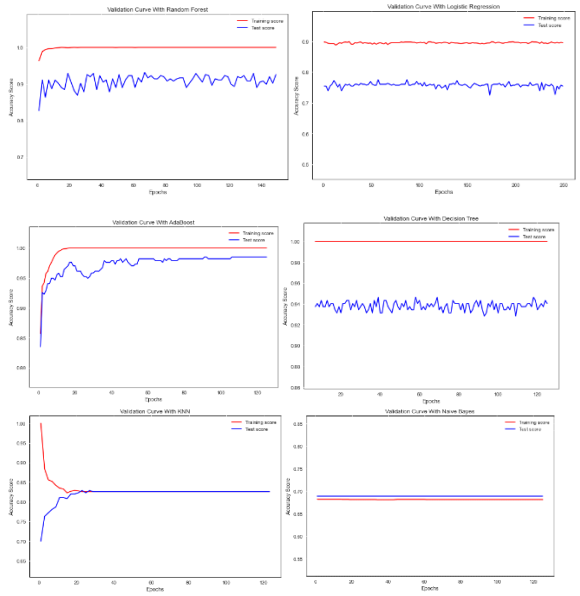

**Figure 3.** Comparative Analysis of various ML models

Apart from accuracy of different models, comparative analysis is also per-formed in terms of AUC as illustrated in Fig.4.

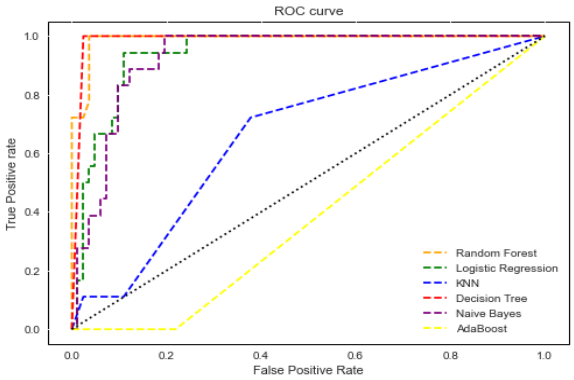


**Figure 4.** Comparative Analysis for ROC curve of various ML models

From comparative analysis illustrated in Fig. 4 it is obvious that AUC for RF outperform other ML models. Further, the results demonstrated in Table 2, Fig. 3 and Fig. 4 also indicate that ensemble models like RF and AdaBoost outperforms traditional ML models. This outperformance by RF and AdaBoost is owing to the underlying working principle of ensemble models that aims towards escalation in the performance of traditional models by combining the results from different models [14-15].

During the result analysis, it is observed that if age > 36, there is a negative propensity for clinical pregnancy and if age >40, the probability of a clinical pregnancy dramatically declines. Further, the propensity of clinical pregnancy is positively correlated to the count of embryos transferred in the same IVF cycle. The transfer 3 to 4 embryos demonstrated little effect on clinical pregnancy when compared to 1 or 2 embryos. Also, the duration of infertility is found to be negatively correlated with clinical pregnancy. Also, the transfer of frozen embryos is positively correlated with clinical pregnancy when compared to fresh embryo which is negatively correlated. Thus, the obtained results demonstrate the effectiveness and efficiency of ML models in predicting the success rate of IVF.

## 5. Conclusion and Future Scope

This study attempted to identify variables that could affect clinical pregnancy outcomes and interactions among different variables. In order to validate the belief, dataset is taken that has data of IVF patients during the period of 2007 to 2019. In order to determine the most optimal ML model, different models are employed and compared in terms of various performance metrics. During the comparative analysis, it is observed that Random Forest outperforms all other ML models in terms of accuracy and AUC etc. Also, it is observed that age of women, and TheDailyGn are the most significant features to determine the success outcome of IVF followed by count of frozen embryos. For now, the proposed work is a classification model which can be extended to predict the probability of clinical pregnancy. Also, the method can be extended so as

to suggest methods for enhancing the chances of pregnancy. Also, the image of embryos can be used to achieve clinical pregnancy. Although authors have proposed employment of ML models for success rate prediction of IVF based on various factors, but lifestyle of the subject also plays a crucial role and hence must be somehow incorporated. This has a constraint that information on lifestyle-related factors is limited.

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