RESEARCH ARTICLE OPEN ACCESS

# A Review of Soft Computing Used in Assisted Reproductive Techniques (ART)

Ajay S. Patil
School of Computer Sciences
North Maharashtra University
Jalgaon – India

**ABSTRACT**
Nearly eighty million people all over the world are suffering from infertility related problems. This problem has aggravated due to several reasons like change in lifestyle, infections, genetic issues, postponed childbearing, etc. Assisted reproductive technology (ART) is the technology used to achieve pregnancy using several types of medical procedures. ART involves three basic procedures viz., intrauterine insemination (IUI), in-vitro fertilization (IVF), intra cytoplasmic sperm injection (ICSI) and are generally carried out in stages. The overall success rate of the treatment is very less, which makes a negative impact on the patient's psychology seeking ART treatment. This psychological change also affects the practitioners to deal with patients. The success rate of the fertility treatment is based on the experience and techniques applied by every individual practitioner. The current challenges that the ART practitioners are facing is to improve the treatment results. It is therefore necessary to use computing techniques and machine learning techniques to assist the medical practitioner to predict or get better results for the treatment administered. This paper reviews soft computing techniques applied in the field of ART on the data available at ART clinics and sperm banks. This review throws light on various soft computing techniques used in the field of ART and will also help to study several issues for further improvement.

***Keywords:-*** ICSI, ART, IUI, IVF

## I. INTRODUCTION

There are around millions of infertile couples in India and all over the world who are seeking the fertility treatment. According to WHO (World Health Organization), ICMR (Indian Council of Medical Research) [1] and other sources the number of infertile couples will increase in the coming years. During the process of fertility treatment the anxiety with infertility can challenge the relationship of the infertile couples. The psychological stress and expenses of multiple clinic visits, testing, treatments, and surgical procedures can be overwhelming for patients. The fertility specialist has different approaches for conducting the fertility treatment. Current success rate of fertility treatments is less than 30% [2]. Practitioners need to do the various types of analysis at different stages of treatment cycles. Today the practitioners are falling short of such analytical techniques. Hence there is a growing need of designing soft computing to meet the demands of the specific requirements in handling medical data. These techniques will assist the medical practitioner in decision making during the course of ART treatment. The paper is divided into four sections. The Introduction section gives an introduction to the paper and details the organization of the paper. The second section describes the various types of ART techniques in brief. The third section focuses on the soft computing techniques used by researchers to improve the ART treatment in the various stages of infertility. The fourth concludes the paper.

## II. ART TECHNIQUES

ART stages consist of ovulation induction, IUI (IntraUterine Insemination), IVF (InVitro-fertilization) and ICSI (Intra-cytoplasmic sperm injection). The fertility treatment is conducted into three stages, first stage is OI/IUI (intrauterine insemination), this is the first phase of treatment and also less expensive compared to IVF and success rate is very less below 10% [1]. Second stage is IVF (in-vitro fertility), the success rate is too high as compared to IUI. Third stage is ICSI, intracytoplasmic sperm injection. The national average success rate for ICSI for women aged less than 35 years

is around 29 percent [3]. The details of these techniques are as under:

### 2.1 Intra-Uterine Insemination

Intrauterine insemination is the first phase of ART that helps the infertile couples to conceive the pregnancy. IUI is a type of artificial insemination which involves placing washed and concentrated sperm inside a woman's uterus to facilitate fertilization. The goal purpose of IUI is to increase the number of sperm that reach the fallopian tubes and subsequently increase the chances of successful fertilization. Depending on the causes or reasons for infertility, IUI can be coordinated with fertility medicines. Ovulation induction is used for women who produce low levels of hormones necessary for ovulation, and in those who do not ovulate at all. Ovulation induction uses drug treatment to encourage the ovaries to release eggs, so as to maximize the chance of conception through IUI. More specifically, in this method of treatment the ovarian follicles are induced with follicle stimulating hormones (FSH). As outcome in the middle of the menstruation cycle, the numbers of mature follicles are generally higher than the number of follicles normally obtained during natural process. In the natural cycle, one or two follicles will mature and release oocytes, whereas when ovulation induction treatment is administered, it is seen that ten such follicles mature. It is also observed that the sizes of the artificially stimulated follicles are comparatively larger than the one produced in natural cycles. The overall success rate of IUI is very less.

### 2.2 In–Vitro Fertilization

IVF is an assisted reproductive technology (ART) in which one or more eggs are fertilized outside a female's body by manually combining an egg and sperm in a laboratory dish, and then transferring the embryo to the uterus (womb). This technology has been successfully applied to human reproduction since 1978[ 2]. IVF can be used to treat infertility in patients that have blocked or damaged fallopian tubes, removed fallopian tubes, genetic disorder, male infertility with decreased sperm count or sperm motility, ovulation disorders, premature ovarian failure, uterine fibroids and other unexplained infertility problems.

### 2.3 Intra Cytoplasmic Sperm Injection

Intracytoplasmic sperm injection (ICSI) is the most successful form of treatment for men who are infertile and is used in nearly half of all IVF treatments. ICSI only requires one sperm, which is injected directly into the egg. The fertilized egg (embryo) is then transferred to the uterus. ICSI has been applied increasingly around the world to alleviate problems of severe male infertility in human patients who either could not be assisted by conventional IVF procedures or could not be accepted for IVF because of presence of too few motile and morphologically normal sperm.

## III. COMPUTATIONAL TECHNIQUES

Kathleen Hwang et al., has extensively reviewed different medical factors those can be used to detect the infertility among the patients [4]. Zhenjun Yang et al., proposed methods for retrieving similar cases from the laboratory results database. In their experiment they had selected around 3000 cases of blood count. Using the Mahalanobis distances calculated that around 95% of the similar cases were retrieved [5]. Davis et. al. [3] used datasets from Westmead Fertility clinic, Westmead hospital, Australia. Each record of the dataset belongs to couple undergoing treatment for ART. The dataset consisted of 1597 records related to IUI treatment, 762 records related to ovulation induction and had about 104 attributes. The dataset contains all necessary details of the patients. Davis et. al. developed clinically modified information fuzzy network (CMIFN) algorithm and modified composite association rule (MCAR) algorithm and also compared the experimental results obtained from them. These algorithms can be used to categorize patients into groups most suitable for particular treatment cycles. But the datasets for these algorithms were very small; they need to be worked out on much more large data sets. [3]. Kooptiwoot [6] & Salam [7] proposed a variation of information theoretic network approach by using human expert guidance to mine IUI (Intra Uterine Insemination) data. The information theoretic approach incorporates fuzzy methodology and contains complex statistical calculations. The researchers therefore developed the new variation approach by adding up the medically important information obtained from human expert to build the information theoretic network. They compared the results of information theoretic network model from the original approach with that of the

information theoretic network model from the variation approach. They found that their new algorithm gave better results than the original information theoretic network approach. They suggested possible modifications to IUI treatment plan so as to improve the success rates of treatment. The new approach is able to predict the success of pregnancy based on the values of the level of Luteal progesterone, gonadotrophin, oestradiol. According to the expert opinion the results from the variation approach (human expert guidance) are better than the results from the original algorithm[6,7]. Chih-Chuan Chen et al. [8] and Leah Passmore et al. [2] tried to develop the predictive model based on different algorithms that can be used for different types of prediction related to fertility treatment. They had used knowledge discovery technique incorporated with PSO (Particle Swarm Optimization) [8] and C5.0 [2] algorithm respectively. Through this study they build a predictive model which not only can predict IVF outcome more accurately, but also can generate a set of explicit rule for easy applications. Chih-Chuan Chen et al. developed a repertory grid to help select attributes to implement the data mining technique. Each instance of the record consisted of ten attributes.

Table 1: THE COMPARISON RESULTS OF THE IVF DATASET

| Title | PSO | Decision Tree J48 | Naïve Bayes | Bayes Net | MLP ANN |
|---|---|---|---|---|---|
| Accuracy | 73.03 | 68.96 | 66.67 | 65.13 | 69.57 |
| Times of Win (test) | - | 69.00 | 82.00 | 94.00 | 69.00 |
| Times of Win (train) | - | 100 | 100 | 100 | 100 |
| Rank | 1 | 3 | 4 | 5 | 2 |

The work was implemented in MATLAB and made use of 10-fold cross validation. The results obtained have proved that the proposed technique can exploit rules approved by the gynecologist/obstetrician and the assistant both justifiability and comprehensibility. They compared the classification performance of PSO-MC with decision tree J48, Naïve Bayes, Bayes network, and multi-layer perceptron. The results obtained are tabulated below (table 1). The results obtained indicated that when applied to IVF database, the proposed PSO (Particle Swarm Optimization) rule extractor can generate comprehensible rule set for obstetricians and gynecologists to use and it is competitive on accuracy compared to many existing classifiers in literature. Chances of pregnancy using IVF for a given patient is a difficult question as it involves hundreds of parameters involved during each IVF cycle [8]. J.R. Trimarchi et al. proposed mathematical modeling to calculate the outcome of an IVF cycle. They performed two experiments using C5.0 decision trees, in the first only age was considered as predictor and in the second they considered a dozen attributes amongst nearly a hundred attributes. The first experiment gave an accuracy of 56% whereas the second gave 75%. This indicates that the results improve when more than only one predictor variable is considered. This work has also proved the results obtained from data mining algorithms agreed with the traditional statistical methods [9]. In another work Leah Passmore et al. used C5.0 decision tree models to predict success or failure of IVF cycles. Their dataset was a database constructed by Women and Infants Hospital in Providence, Rhode Island. The goal of this work was to evaluate the feasibility of decision tree models in predicting whether a given patient undergoing IVF would be pregnant or not. They have stated advantages of using the decision tree models viz., they can be designed and implemented with ease, understood easily and can be converted into rule sets etc.. In order to ensure assessment in a better manner logistic regression model was considered, secondly feature selection techniques like attribute winnowing, statistical feature selection, and wrapper approach were added to C5.0 decision tree models in order to optimize the results. The decision tree model with attribute winnowing gave the best performance (69.5%) compared to decision tree model with full feature set (67.4%) , decision tree model with wrapping (63.1%) and decision tree model with statistical feature selection (66.5%). It is observed that only winnowing approach gives improved results, whereas feature selection using wrapping and statistical feature selection lowered the results. In this work the selected dependent variable was dichotomous (i.e. 1: successful pregnancy, 0: unsuccessful pregnancy) and the 100 independent variables (patient characteristics) were a mixture of

continuous and categorical variables. It was observed that the decision tree approach is a good alternative to the statistical models constructed by hand. Hence the decision tree model shall save time as it can be refreshed periodically as and when needed [2]. According to Linda et. al. it was a common practice in IVF treatment to transfer multiple embryos to increase the probability of pregnancy. However, multiple embryo transfer may result into of multiple pregnancy and other related complications. Hence single embryo transfer preferred to reduce the risks involved with multiple pregnancy. However, single embryo transfer without any selection based on the patient's characteristics and the quality of the embryo, leads lowers the probability of pregnancy. In such case the patient has to undergo multiple treatments which in turn results into financial overhead along with physical and emotional trauma. Therefore in order to administer single embryo transfer, patient-specific assessment of the expected result of the transfer needs to be worked out. Linda et. al. focused on the use of Bayesian network classifiers and logistic regression models to calculate the expected result for single embryo transfer to the patient based on the embryo and patient data. They reviewed various Bayesian network classifiers and theoretically compared each of them with the logistic regression model. They have advocated the use of Bayesian network model, but it is observed that the Bayesian network classifier implemented did not outperform the logistic regression model. But they were successful in showing that the Bayesian network classifiers show comparable behavior and can be further improved to give better results. [10]

**Table 2: Computational Techniques used in ART**

| Author(s) | Techniques Used |
|---|---|
| Leah Passmore et al.[2] | C5.0 Decision Tree (Various Feature Selection) |
| Davis et. al.[3] | CMIFN, MCR |
| Zhenjun Yang and et al [5] | Mahalanobis and Euclidean Distance |
| Kooptiwoot et.al [6,7] | Information Theoretic Network Variation Approach (Human Expert Guidance) |
| C Chen et al.[8] | PSO, Decision Tree J48, Naïve Bayes, Bayes Net, MLP ANN |
| J.R.Trimarchi et al.[9] | C5.0 Decision Tree |
| Kowalcek et. al. [11] | SPSS 5.0 |
| Asli Uyar et. al. [12] | Naïve Bayes Classifier |
| Wittemer et al [13] | Multiple Variant Discriminant |
| Vahdani et. al. [14] | Interval-Valued Fuzzy Analytic Network Process |
| Malinowski et. al. [15] | Optimization approach (ANN) |
| R.S. Guh et al. [16] | Hybrid Intelligence Method (Integrating genetic algorithm and decision learning techniques) |
| A. Narges et. al. [17] | K-means clustering |

Asli Uyar et. al. used the Naïve Bayes classifier to an original IVF data set for predicting the outcome of implantation. They used the dataset available from an IVF Unit of German Hospital in Istanbul. They have investigated the effects of under sampling and over sampling of IVF data and moving of the decision threshold of the Naïve Bayes Classifier for prediction of outcome of implantation. Weka Mining tools were used for the experimentation work. The results showed that 0.3 is the best threshold for classification of embryos. The results also show that as increasing the number of positive embryo samples and reducing the number of negative embryo samples raise the number of positive predictions [11]. Ingrid Kowalcek et. al. carried out a prospective investigation by processing the data received from 115 couples using the software package SPSS (Release 5.0) and estimated their chances for successful in-vitro fertilization. The couples were interviewed to predict the success of IVF on a scale of 0 to 100. The several factors on which the analysis was done for the couples was based on age, education, length of time of trying to get pregnant, causes of infertility and experience of treatment. Statistical techniques such as Wilcoxon test, Kruskall-Wallis-test, Standard Deviation were used [11]. Asli Uyar and et. al. proposed a intelligent system to improve the success rate of pregnancy. They used SVM (Support Vector Machine) for training data on past historical data. The system was designed to predict the pregnancy after transferring the embryos. In this experiment around 17 features related to the patient characteristics, treatment method, morphological

parameters of the embryo, results from diagnosis tests were incorporated. The model prediction accuracy was 87.2%. The work has shown that SVM based learning system is a good tool to predict pregnancies in a personalized manner and equates with the most experienced embryologist [12]. Christtane Wittemer et. al. used multiple variant discriminant factorial analysis on sperm analysis in order to obtain embryos. They discovered nine nonconventional parameters that induce to define two classes of semen. The records are classified into the two fertile and infertile groups in 74.4% of the cases. [13]. Vahdani et al., develop the interval-valued fuzzy Analytic Network Process [ANP (IVF-ANP)] to solve multi-criteria decision making problems (MDMP) since it allows interdependent influences specified in the model and generalizes on the super matrix approach. Pawel Malinowski et al. worked out the shortcomings of classical statistical methods and also showed that data mining methods are more accurate analysis of information, significantly more accurate than the traditional statistical methods [14]. They found a small SVM classifier performance that has been noticed in Uyar's et al. work [12], may be the result of a large number of discrete features [15]. Ruey-Shiang Guh et al. proposed the hybrid intelligence method which integrates genetic algorithm and decision learning techniques for knowledge mining of an IVF medical database. The proposed method can be used by specialists in predicting the IVF outcome, to tailor the treatment administered to the individual. Their work is is currently accepted as an interesting discovery according to experts. Based on this work they have also designed an expert tool to predict the outcome of IVF treatment [16]. Aghabeigi Narges et al. worked on IVF data using different data mining techniques. They developed the descriptive algorithm related to ICSI (Intra-Cytoplasmic Sperm Injection) of IVF treatment. They applied K-means clustering to the data that was segmented with respect to male and female partner age. As a result of which the success of pregnancy was observed in each step after improving the process of treatment through k-means clustering [17].

## IV. CONCLUSION

From the survey of all the above resources it is been discussed that many soft computing techniques are involved in the field of IVF. Most of the techniques that are developed are used for predicting the outcomes of treatments, analyzing the treatment cycles. The study reveals that there is still scope for implementing the various methodologies for improving the results related to fertility treatment. The comparative study of various results has also exposed that there are certain areas where the soft computing techniques can be introduced, such as analysis of semen sample, analysis of patient profile, matching the semen donors, analyzing the embryo samples etc. Today matching of sperm donor characteristics with the recipient requirement is been done manually. Although the current softwares that are used for matching the sperm donor has very less accuracy, since it is been done using simple query structure. In most of the research done the data comparison is based on limited parameters. It is been found that there is a scope to introduce the soft-computing techniques for profiling the sperm donors. The research conducted in this field has a social perspective and can help the society as well.

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