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REVIEW OF COMPUTER VISION APPLICATION IN IN-VITRO FERTILIZATION: USING DEEP LEARNING TECHNIQUES

[1]Prerana Prasanna Deshpande.,[2]Dr.Dnyaneshwari Patil,[3]Dr.Yogesh Rajput

[1] Assistant Professor,[2] Assistant Professor,[3] Assistant Professor

[1]Computer Science,

[1]Vivekanand Arts, Sardar Dalipsingh Arts and Science College , Aurangabad ,India

Abstract: Embryo grading is a tool that helps embryologists and physicians during an in vitro fertilization (IVF) treatment to determine, exactly which embryos to transfer, the optimal day of transfer and the appropriate number of embryos. To overcome infertility problems, IVF technique is used. In this paper, observe a new method for assessing blastocyst quality using a deep learning approach. Through a comprehensive review, we have to discovered multiple approaches of implementing deep learning techniques, each of them having varying degrees of success. For constructing automated systems to find best embryo for implantation, this system can evaluate and give explanations and comments the development stages of an embryo.

Index Terms - **deep learning, neural network, generative adversarial network, synthetic images, SSS-Net**

I. INTRODUCTION

Infertility is the inability to conceive a child. Infertility has different causes including male factors as well as female factors. Now a days it is one of the major health issue in society. To overcome this problem of infertility there are some treatments are carried out. ART (Assisted Reproductive Treatment) is used to treat infertility which includes techniques like IVF (In Vitro Fertilization), ICSI (Intracytoplasmic Sperm Injection) etc. The selection of embryo for embryo transfer is a significant step. It has always been challenging for embryologists to select a proper embryo. If proper embryos are not selected then it affects the pregnancy rate. The quality of the embryo is one of the predictors of successful implantation of the embryo. The transfer of poor quality of embryo may lead to abortion and decrease in clinical pregnancy rate [1].

When it's time to transfer your embryo(s) into the uterus during an IVF cycle, the embryos are carefully observed, inspected and graded as they develop. The embryo(s) with the highest grade typically have the best chance of developing into a successful pregnancy and are chosen to transfer. In order to understand how our embryologists grade embryos and what the grades mean, it is helpful to track the development cycle of an embryo [1].

Embryo grading is a tool that helps embryologists and physicians during an IVF treatment to determine, exactly which embryos to transfer, the optimal day of transfer and the appropriate number of embryos to transfer.

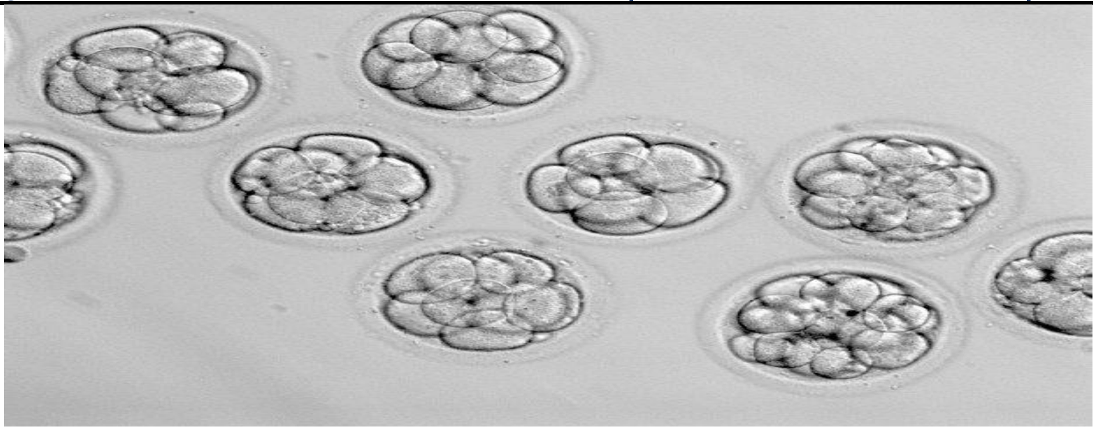


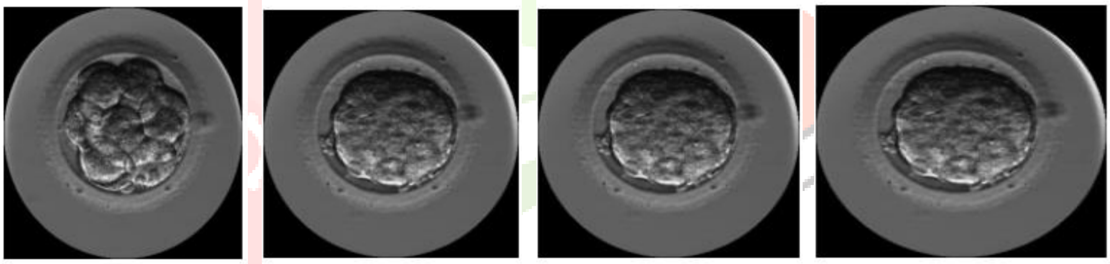
Fig 1.Understanding Embryo grading[1]

II. Embryo Grading:

Embryo Grade	Description
Grade 1	Cells are of equal size; no fragmentation seen
Grade 2	Cells are of equal size; minor fragmentation only
Grade 2.5	Cells are mostly of equal size; moderate fragmentation
Grade 3	Cells are of equal size; no fragmentation to moderate fragmentation
Grade 4	Cells are of equal or unequal size; fragmentation is moderate to heavy

Table 1.Embryo Grading [1]

III. Type Style and Fonts



(a) (B) (C) (D)

Figure 1

Figure 1 (a) : Cleavage (day 1-3): embryo cells are dividing and boundaries between cells are clearly visible

Figure 1 (c) : Morula (day 4): cells have increased adhesion (become more attached)

Figure 1 (d) : Blastocyst (day 5): Inner cell mass, trophectoderm, and blastocoel struct ures are developed

IV. Literature Review

In year 2019, Pegah Khosravi, Ehsan Kazemi , Qiansheng Zhan , Jonas E. Malmsten , Marco Toschi , Pantelis Zisimopoulos, Alexandros Sigaras, Stuart Lavery , Lee A. D. Cooper , Cristina Hickman , Marcos Meseguer, Zev Rosenwaks , Olivier Elemento, Nikica Zaninovic and Iman Hajirasouliha performed a work, "Deep learning enables robust assessment and selection of human blastocysts after in vitro fertilization". They postulated that an AI approach trained on thousands of embryos can forecast human embryo quality without human intervention. They implemented an AI approach based on deep neural networks (DNNs) to select highest quality embryos using a large collection of human embryo time-lapse images (about 50,000 images) from a high-volume fertility center in the United States. They developed a framework (STORK) based on Google's Inception model. In conclusion, their AI-driven approach provides a reproducible way to assess embryo quality and uncovers new, potentially personalized strategies to select embryos [2].

Tsung-Jui Chen, Wei-Lin Zheng, Chun-Hsin Liu , Ian Huang , Hsing-Hua Lai , Mark Liu,Binflux, Inc., Taipei, Taiwan performed a work "Using Deep Learning with Large Dataset of Microscope Images to Develop an Automated Embryo Grading System". They used deep learning with large dataset of microscopic embryo images to develop an automated grading system for embryo assessment. Using a pre-trained network trained on the ImageNet dataset as convolution base, they applied Convolutional Neural Network (CNN) on embryo images, using ResNet50 architecture to fine-tune ImageNet parameters. The predicted grading results was compared with the grading results from trained embryologists to evaluate the model performance. The results showed an average predictive accuracy of 75.36% for the all three grading categories: 96.24% for blastocyst development, 91.07% for ICM quality, and 84.42% for TE quality[3].

Gargee Vaidya , Shreya Chandrasekhar , Ruchi Gajjar, Nagendra Gajjar , Deven Patel and Manish Banker performed a work "Time Series Prediction of Viable Embryo and Automatic Grading in IVF using Deep Learning". In this paper they develop a deep learning based method to perform the automatic grading of the embryos using time series prediction with Long Short Term Memory (LSTM) and Convolutional Neural Network (CCN). They use CNN to extracts the features of the images of embryos , sequence of such features are then fed to LSTM for time series prediction, that gives the final grade. The proposed model gives an accuracy of 100% on training and validation[4].

Vidas Raudonis, Agne Paulauskaite-Taraseviciene, Kristina Sutiene and Domas Jonaitis performed a work "Towards the automation of early-stage human embryo development detection". They proposed a model based deep learning for automatic embryo grading. The proposed model used to detect human embryo development stages by focusing on five different stages. This proposed method have two major stapes. In first method the location on an embryo in the image is detected by using Haar feature based cascade classifier and leveraging the radiating lines. In second step, a multi class prediction model is developed to identify a total cell number in the embryo using the technique of deep learning. This proposed method gives an accuracy of at least 90% in the detection of embryo location. By using deep learning approach to identify the early stages of embryo development resulted in the overall accuracy of over 92% using selected architectures of Convolutional Neural Networks[5].

Darius Dirvanauskas, Rytis Maskeliūnas, Vidas Raudonis , Robertas Damaševičius and Rafal Scherer, department of Multimedia E performed a work "HEMIGEN: Human Embryo Image Generator Based on Generative Adversarial Networks". They trained the human embryo images by using deep neural network (DNN). The proposed algorithm used generative adversarial network (GAN) to generate cell state images (i.e. one-,two and four cells). They achieved a misclassification rate of 12.3% for the generated images, while the expert evaluation showed the true recognition rate (TRR) of 80.00% (for four-cell images), 86.8% (for two-cell images), and 96.2% (for one-cell images). Texture-based comparison using the Haralick features showed that there is no statistically (using the Student's t-test) significant ($p < 0.01$) differences between the real and synthetic embryo images except for the sum of variance (for one-cell and four-cell images[6]).

Mehryar Abbasi, Parvaneh Saeedi, Jason Auqα Jon Havelockq, performed a work "A deep learning approach for prediction of ivf implantation outcome from day 3 and day 5 time-lapse human embryo image sequences". In this paper they use Artificial intelligence (AI) systems for automatic human embryo assessment. This approach consists of two models. One model evaluates each embryo based on its day-3 attributes, while the second model assesses the same embryo's day-5 image sequence. A Data Length Schedular (DLS) algorithm is developed addressing variations in blastocyst stage sequences' lengths. With an accuracy of 76.9%, the proposed system beats state of the art by 6%[7].

Shanshan Wang , Cong Zhou , Dan Zhang , Lei Chen , And Haixiang Sun , performed a work "A Deep Learning Framework Design for Automatic Blastocyst Evaluation With Multifocal Images". In this study they use Grad-CAM algorithm to visualize all blastocyst stage images in the test set, they found that key features depend on by the classification model were trophectoderm (TE), inner cell mass (ICM) and zona pellucida (ZP). A deep learning approach gives a new method for assessing blastocyst quality. The multichannel combination network showed the best performance among the three proposed models, in that the clearest images from multiple focal depths were chosen and fetched into the VGG-16 (i.e. object detection and classification algorithm) network as different channels. Among different types of CNN models they selected VGG-16 because of its better performance (AUC=0.936) in their dataset. Grad-CAM visualization technology was also used to validate the model and explain how a deep learning model determines blastocyst qualities, which may help embryologists and patients understand that technology[8].

Zihan Liu1 , Bo Huang , Yuqi Cui, Yifan Xu , Bo Zhang , Lixia Zhu , Yang Wang , Lei Jin , And Dongrui Wu , (Senior Member, IEEE), performed work " Multi-Task Deep Learning With Dynamic Programming for Embryo Early Development Stage Classification From Time-Lapse Videos". In this study they use multi-task deep learning with dynamic programming (MTDL-DP) approach for this purpose. To pre-classify each frame in the time-lapse video they first uses MTDL, and then DP to optimize stage sequence. They prove that the one to many MTDL framework gives the best results. As per my knowledge this is the first study that they applies MTDL to early development stage classification of embryo from time-lapse videos[9].

E. Santos Filho, J.A. Noble, M. Poli, T. Griffiths, G. Emerson, and D. Wells , "A method for semi-automatic grading of human blastocyst microscope images". In this paper they propose image segmentation method and classification method of human blastocyst images to develop automating embryo grading system. The segmentation of zona pellucid, trophectoderm (TE) and inner cell mass (ICM) were performed using advanced image analysis techniques. Support Vector Machine classifier is used to calculate fractal dimension and mean thickness of TE and ICM image texture descriptor to characterize morphological characteristics of the blastocyst. The accuracy achieved by using this classifier ranges from 0.67 to 0.92 for embryo development, 0.67 to 0.82 for the ICM classification and 0.53 to 0.92 for the TE classification. The highest accuracy achieved that is 0.92 during the test with 73 balstocysts[11].

Muhammad Arsalan , Adnan Haider, Jiho Choi and Kang Ryoung Park, "Detecting Blastocyst Components by Artificial Intelligence for Human Embryological Analysis to Improve Success Rate of In Vitro Fertilization". In this paper they use a sprint semantic segmentation network (SSS-Net) is proposed to accurately detect blastocyst components for embryological analysis. This proposed method is based on a fully convolutional semantic segmentation scheme. That provides the pixel-wise classification of blastocyst components. To reduced the cost of network the proposed SSS-Net uses sprint convolutional block (SCB). Publically available human blastocyst image dataset was used for input to SSS-Net. The experimental results confirm that our proposal provides promising segmentation performance with a Jaccard Index of 82.88%, 77.40%, 88.39%, 84.94%, and 96.03% for ZP, TE, BL, ICM [12].

Amjad Hossain, Ph.D., John Phelps, M.D., J.D., LL.M., Ashok Agarwal, Ph.D., Eduardo Sanz, M.Sc., Maha Mahadevan, Ph.D., "A Review of The Society for Assisted Reproductive Technology Embryo Grading System and Proposed Modification". In the review paper they reviewed that the SART embryo grading system categories embryo as "good", "fair" and "poor". This system has limitations because they do not give the best 1-2 embryos in the interest further clinical practice and to transfer fewer embryos. The system, as it is now, lacks criteria for describing the cohort specific best embryo and thus is of limited use in single embryo transfer[13].

E. Santos Filho, J.A. Noble and D. Wells, "A Review on Automatic Analysis of Human Embryo Microscope Images". In this paper they reviewed that the main embryo grading (scoring) system currently in use and review related works on embryo image analysis that could lead to an automatic and precise grading of embryo quality. They also conclude that the use of automated system will save the embryologist time and it may achieve a better selection of embryo for pregnancy. Ultimately, it hoped that computer assisted embryo evaluation will improve and streamline the IVF procedure, reducing costs and increasing the ability of embryologists to identify the better embryo that has more chances to produce a child[14].

Claudio Michael Louis, Alva Erwin, Nining Handayani, Arie A. Polim, Arief Boediono, Ivan Sini, "Review of computer vision application in in vitro fertilization: the application of deep learning-based computer vision technology in the world of IVF". According to authors view, a recent powerful upward movement of AI-based solutions for tasks of automation in IVF has been observed. They discovered multiple approaches of implementing deep learning technology. Each approach have with varying degrees of success. For constructing the automated systems in IVF which could evaluate and even remark the developmental stages of an embryo[15].

V. Comparative Study

Year	Methods	Dataset	Feathers and Accuracy
2019	vector machine (SVM) and RF, and deep learning methods, such as CNN [4]	STORK	---
2019	CNN using ResNet-50 [19]	Stork dataset	Blastocyst, ICM, TE, predictive accuracy of 75.36% for the all three grading categories: 96.24% for blastocyst development, 91.07% for ICM quality, and 84.42% for TE quality.
2021	CNN-LSTN model [10]	---	An ideal accuracy of 100% on training and validation
2019	CNN and Haar classifier [12]	---	Experimental results shows 90% results accuracy and using CNN accuracy reached upto 92%
2019	For training DNN is used GAN is used to generate 1,2,4 cell stage embryo images [7]	---	TRR of 80% for four cell images,86.8% for two cell images, 92% for one cell images
2022	SSS-NET [14]	---	Zona Pellucida (ZP), TE, Blastocoel (BL), ICM a Jaccard Index of 84.51%, 78.15%, 88.68%, 84.50%, and 95.82% for ZP, TE, BL, ICM

VI. Conclusion

To overcome infertility problems, IVF technique is used. In IVF good embryo is inserted into women's womb which can lead to pregnancy. In this review paper, we have studied to develop an automated system for grading theses embryos many researchers had been used deep learning techniques and AI (Artificial Intelligence) for classification. Some researchers had used DNN (Deep Neural Network, CNN (Convolutional Neural Network) techniques. Some of the researchers had been used SVM (Supervised Machine Learning).

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