

AI-based Image Recognition for Sperm Morphology and Motility

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Assisted reproductive technologies play a major role in animal reproduction and conservation. Accuracy in semen analysis is an indispensable component for the success of Assisted Reproductive Technologies, as male infertility may contribute up to 40 to 50 % of pregnancy failure cases. The manual analysis of semen may be subjective, time-consuming, and error-prone. It was improved by the introduction of a superior technique, the Computer-Aided Sperm Analysis, which enhanced the examination of viability and kinematic parameters of spermatozoa. Recently, artificial intelligence, especially integrated with deep convolutional neural networks (DCNN), has depicted immense potential in enhancing the efficiency of semen analysis. Such systems efficiently and speedily perform the objective analysis of sperm morphology and motility through image recognition as they are trained with massive annotated datasets through supervised learning.

Keywords: *Assisted Reproductive Technologies, Artificial Intelligence, Image Recognition, Semen Analysis, CASA*

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Introduction

Assisted reproductive technologies (ARTs) like artificial insemination, in vitro embryo production, embryo transfer, intracytoplasmic sperm injection, gamete/embryo sexing, gamete/embryo cryopreservation, gamete/embryo micromanipulation, somatic cell nuclear transfer, and genome resource banking are playing a major role in farm animal and wild animal reproduction. In the case of farm animal reproduction, ARTs are playing a major role in enhancing economic returns by the rapid multiplication of highly productive farm animal germplasm. The production and distribution of frozen semen from bulls of high genetic merit, coupled with artificial insemination, is a breakthrough that has enhanced the pace of multiplication of highly productive farm animals. In case of wild animal reproduction, ARTs are helpful in conservation of endangered wild animal species (Ciani et al., 2008; Ciani et al., 2012).

The success of artificial insemination technology lies in the correct and rapid analysis of semen samples from male animals. Both male and female infertility may contribute to the pregnancy failure, but male infertility may contribute to 40-50% of cases (Hirsh, 2003). Male fertility is highly significant in the case of farm animals, as a semen sample from a male animal is used for artificial insemination in several thousand females. Thus, proper examination of semen samples is important for the success of artificial insemination programmes and other ARTs. However, the manual analysis of semen is time-consuming, as well as prone to errors (Douglas et al., 2021).

Development of artificial intelligence (AI) in semen examination has shown potential to improve the process of semen analysis, by enhancing the speed of semen analysis, as well as reducing the amount of error in semen analysis (Baker and Xiang, 2023; Kakkar et al., 2025). The Computer-Aided Sperm Analysis (CASA) system is one such technological advancement that is being integrated with AI-based image processing to improve semen analysis. Artificial intelligence-based image processing has facilitated semen examination through better sperm selection and the tracking of individual sperm cells. These techniques are highly efficient with reproducible results. They facilitated the efficient analysis of sperm functional parameters, the most important of which include motility, morphology, and DNA integrity, as well as helping to overcome the limitations of manual analysis (Baldán et al., 2025).

Computer-Aided Sperm Analysis (CASA): the transformative advancement in semen analysis

The introduction of CASA since 1980 has led to a decrease in variability in semen analysis, and as a result, semen analysis has become more standardized. CASA systems consist of computer software-based automatic application of cameras to analyze the data obtained through microscopic evaluation of semen, and interpret the results of semen parameters. They had been developed to provide accurate information about different sperm functional parameters like sperm kinematics, concentration, and viability by means of continuous image capturing through video cameras, their processing through video image digitization, and analysis through computers. Their use spread throughout laboratories and clinical practice, reducing the time and errors in semen analysis (Finelli et al., 2021). The first commercial CASA developed was CellSoft by CRYO Resources Ltd in 1985, and the next CASA developed was HTM-2000 by Hamilton-Thorn in 1986. The CellTrack system from Motion Analysis Corporation was a CASA system developed in the early 1990s. The commonly reported sperm kinematic parameters by the CASA include: Total Motility, Progressive Motility, Curvilinear Velocity (VCL), Average Path Velocity (VAP), Straight Line Velocity (VSL), Amplitude of Lateral Head Displacement (ALH), Beat Cross Frequency (BCF), Straightness (STR), Linearity (LIN). Motility is one of the main functional parameters associated with the fertility of spermatozoa. The important motility parameters include: Total motility, defined as the ratio of the number of motile cells to the total cell concentration, while progressive motility is the percentage of spermatozoa moving in the forward direction, which is crucial for fertility. VCL represents the total distance travelled by the sperm (obtained by adding point-to-point distances along the curved path) divided by the time. In contrast, VSL is obtained by dividing the distance between the first and last points of the sperm path by the time taken, and VAP is obtained by dividing the total smoothed average path (by neglecting the curves in the path), followed by the spermatozoa, by the time taken. Presently, more than 12 CASA systems are marketed around the world; however, the most popular one is the IVOS Sperm Analyzer of Hamilton Throne, along with the use of the Makler chamber and Leja slide. It supports an image capture rate of 60 frames per second, which provides the highest level of accuracy for analysing spermatozoa kinematic parameters, reducing errors, as well as allowing subjective examination of semen (Sethi et al., 2021).

Artificial intelligence (AI) in semen examination

It has been reported that male factor contributes about 50% in infertility and pregnancy failure cases (Agarwal et al., 2015). Regardless of several ARTs being used nowadays, the successful conception rates have not increased over the past few years (Fauser 2019), and sperm selection can be implicated as a major contributing factor in this (Oseguera-Lopez et al., 2019). When the semen sample is examined by the embryologist, they cannot spend much time examining the entire semen sample. As a result, semen examination largely depends on manual examination, which is subjective and error-prone, affecting the success of ARTs (Barroso et al. 1999). Artificial intelligence (AI) has recently evolved as a solution to the subjectivity, errors, variability, and delays in semen examination (Bormann et al., 2020). Application of AI is highly useful in the analysis of pictures at a higher rate in terms of frames per second than the human eye, as well as an enhanced ability to recognise different patterns during semen analysis (Stockman and Shapiro, 2001).

AI and machine learning algorithms have shown great potential in analysing sperm morphology according to WHO-led criteria, which is helpful in ARTs like ICSI and IVF. A deep neural network is an algorithm structure that helps in semen examination, like the classification of normal sperm from stressed sperm (Butola et al. 2020), and the prediction of pregnancy outcomes (Kandel et al. 2020). The efficiency of artificial intelligence in analysing visual data is further enhanced by the application of deep convolutional neural networks (DCNN). DCNNs mimic the human brain, especially the visual cortex, in analyzing the visual data. They are highly advanced, fabricated similarly to the human brain, consisting of multilayered neural networks (Mienye et al., 2024). DCNNs are trained to recognise images by providing them with a large number of annotated datasets, which is a part of supervised learning. Data is annotated through classification, tagging, bounding boxes, etc., which is crucial in the training of DCNNs or machine learning (Hong et al., 2017). DCNN models enabled AI to estimate and report the proportion of spermatozoa in the WHO motility categories with significantly lower error than the baseline (Andersen et al., 2024). There is a requirement for continuous training of these DCNN-integrated AI models with annotated datasets to further enhance their efficiency in analyzing semen samples with higher accuracy and speed.

Conclusion

The shift towards Computer-Aided Sperm Analysis from manual microscopic semen examination represents a significant advancement in enhancing the efficiency of semen analysis. The semen analysis process is getting quicker, more accurate, and objective through the integration of AI into CASA systems. The supervised learning of deep convolutional neural networks has shown an impact on further enhancing the efficiency of AI-based semen examination. Consistent improvement of fertility outcomes in livestock and human ARTs requires continuous training of DCNN-integrated AI models with massive annotated datasets to further improve the accuracy of semen examination.

Conflict of Interest: The authors declare that they have no conflict of interest.

References

Agarwal, A., Mulgund, A., Hamada, A., & Chyatte, M. R. (2015). A unique view on male infertility around the globe. *Reproductive Biology and Endocrinology*, 13, Article 37.

- Andersen, J. M., Witczak, O., Due, E. U., Hicks, S., Thambawita, V., Björndahl, L., Riegler, M., & Haugen, T. B. (2024). Sperm motility assessed by deep convolutional neural networks. *Reproductive BioMedicine Online*, 48(1), 104060.
- Baker, S., & Xiang, W. (2023). Artificial intelligence of things for smarter healthcare: A survey of advancements, challenges, and opportunities. *IEEE Communications Surveys & Tutorials*, 25, 1261–1293.
- Baldán, F. J., García-Gil, D., & Fernandez-Basso, C. (2025). Revolutionizing sperm analysis with AI: A review of computer-aided sperm analysis systems. *Computation*, 13, 132.
- Barroso, G., Mercan, R., Ozgur, K., Morshedi, M., Kolm, P., Coetzee, K., Oehninger, S. (1999). Intra- and inter-laboratory variability in the assessment of sperm morphology by strict criteria: Impact of semen preparation, staining techniques and manual versus computerized analysis. *Human Reproduction*, 14(8), 2036–2040.
- Bormann, C. L., Thirumalaraju, P., Kanakasabapathy, M. K., Kandula, H., Souter, I., Dimitriadis, I., Shafiee, H. (2020). Consistency and objectivity of automated embryo assessments using deep neural networks. *Fertility and Sterility*, 113(4), 781–787.e1.
- Butola, A., Popova, D., Prasad, D. K., Ahmad, A., Habib, A., Tinguely, J. C., Mehta, S. K. (2020). High spatially sensitive quantitative phase imaging assisted with deep neural network for classification of human spermatozoa under stressed condition. *Scientific Reports*, 10, 13118.
- Ciani, F., Cocchia, N., Esposito, L., & Avallone, L. (2012). Fertility cryopreservation. In B. Wu (Ed.), *Advances in Embryo Transfer* (pp. 225–248). IntechOpen.
- Ciani, F., Cocchia, N., Rizzo, M., Ponzio, P., Tortora, G., Avallone, L., Lorzio, R. (2008). Sex determining of cat embryo and some feline species. *Zygote*, 16(2), 169–177.
- Douglas, C., Parekh, N., Kahn, L. G., Henkel, R., & Agarwal, A. (2021). A novel approach to improving the reliability of manual semen analysis: A paradigm shift in the workup of infertile men. *World Journal of Men's Health*, 39(2), 172–185.
- Fausser, B. C. (2019). Towards the global coverage of a unified registry of IVF outcomes. *Reproductive BioMedicine Online*, 38(2), 133–137.
- Finelli, R., Leisegang, K., Tumallapalli, S., Henkel, R., & Agarwal, A. (2021). The validity and reliability of computer-aided semen analyzers in performing semen analysis: A systematic review. *Translational Andrology and Urology*, 10(7), 3069.
- Hirsh, A. (2003). Male subfertility. *BMJ*, 327, 669–672.
- Hong, S., Kwak, S., & Han, B. (2017). Weakly supervised learning with deep convolutional neural networks for semantic segmentation: Understanding semantic layout of images with minimum human supervision. *IEEE Signal Processing Magazine*, 34(6), 39–49.
- Kakkar, P., Gupta, S., Paschopoulou, K. I., Paschopoulos, I., Paschopoulos, I., Sifaka, V., & Tsonis, O. (2025). The integration of artificial intelligence in assisted reproduction: A comprehensive review. *Frontiers in Reproductive Health*, 7, Article 1520919.

Kandel, M. E., Rubessa, M., He, Y. R., Schreiber, S., Meyers, S., Matter Naves, L., Popescu, G. (2020). Reproductive outcomes predicted by phase imaging with computational specificity of spermatozoon ultrastructure. *Proceedings of the National Academy of Sciences*, 117(31), 18302–18309.

Mienye, I. D., Swart, T. G., Obaido, G., Jordan, M., & Ilono, P. (2024). Deep convolutional neural networks: A comprehensive review. Preprints.

Oseguera-Lopez, I., Ruiz-Díaz, S., Ramos-Ibeas, P., & Pérez-Cerezales, S. (2019). Novel techniques of sperm selection for improving IVF and ICSI outcomes. *Frontiers in Cell and Developmental Biology*, 7, 298.

Sethi, M., Shah, N., Kumar, P., Gupta, V., Rohilla, A., Bhatia, N., Kumar, N., Bhakat, M., & Mohanty, T. K. (2021). CASA (computer-assisted semen analysis): As a tool for analysis of bull fertility. *Indian Farmer*, 8(04), 293–299.

Stockman, G., & Shapiro, L. G. (2001). *Computer vision*. Prentice Hall.