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MALE FERTILITY DETECTION USING DETECTRON2 & CSR-DCF

Amod Kumar J[1], Dhanush[2], Elvin D'Sa[3], Shivaraj[4], Sunitha N V[5]

Dept OF CS&E, MITE, Moodabidri, Mangalore[1-4]

Assistant Professor, Dept OF CS&E, MITE, Moodabidri, Mangalore[5]

Abstract: This paper introduces an optimized approach for detecting and tracking sperm in phase-contrast microscopy image sequences, with the aim of improving fertility analysis and sperm behavior studies. The proposed method integrates advanced object detection techniques with a modified multi- object tracking algorithm to achieve superior accuracy and robustness. Through comprehensive experimentation, our approach demonstrates exceptional performance in challenging scenarios such as high-density sperm samples, occlusions, and collisions, achieving an F1 score of 96.61% in tracking accuracy. This optimized algorithm holds significant promise for advancing research in reproductive health.

I. INTRODUCTION

Accurate sperm tracking is essential for effective fertility analysis and reproductive health studies. Conventional single-sperm tracking methods often fail in scenarios involving sperm collisions or overlaps, necessitating the development of more advanced multi-object tracking algorithms. In this context, we propose an optimized multi- object sperm tracking algorithm that combines cutting-edge object detection frameworks with innovative tracking techniques. By seamlessly integrating detection and tracking phases, our approach ensures high precision and reliability in analyzing sperm behavior and fertility potential.

II. FEATURES

Enhanced Object Detection with Detectron2 Our method leverages Detectron2, a deep fully convolutional neural network, for accurate sperm detection in phase-contrast microscopy images. By considering a concatenated sequence of frames, our detection model captures vital motility attributes essential for fertility analysis, thereby enhancing overall detection performance.

Refined CSR-DCF Tracker with Novel Functionalities: The core of our tracking algorithm is based on the CSR-DCF tracker, originally designed for single-object tracking. We extend this framework to handle multiple sperm tracking by incorporating novel functionalities such as the "missing tracks joiner." This innovative feature addresses challenges posed by false positives and false negatives in tracking results, ensuring superior tracking accuracy.

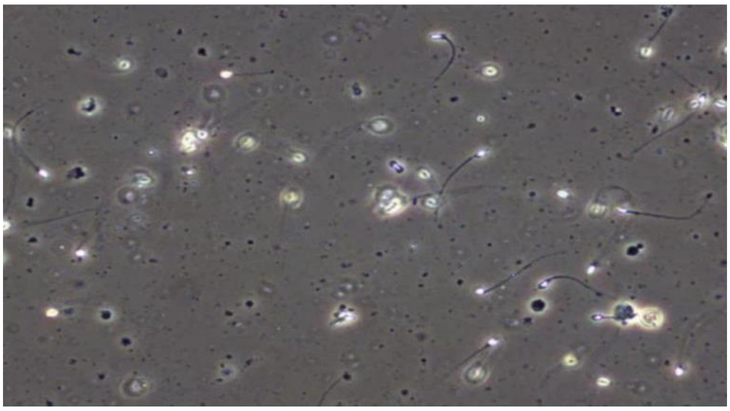

Fig-1: microscopic video frame

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Robustness to Challenging Scenarios: Our optimized approach demonstrates robust performance in scenarios involving high-density sperm samples, occlusions, and collisions. By combining accurate detection with refined tracking capabilities, our method facilitates reliable analysis of sperm behavior and fertility potential, even in the presence of challenging conditions.

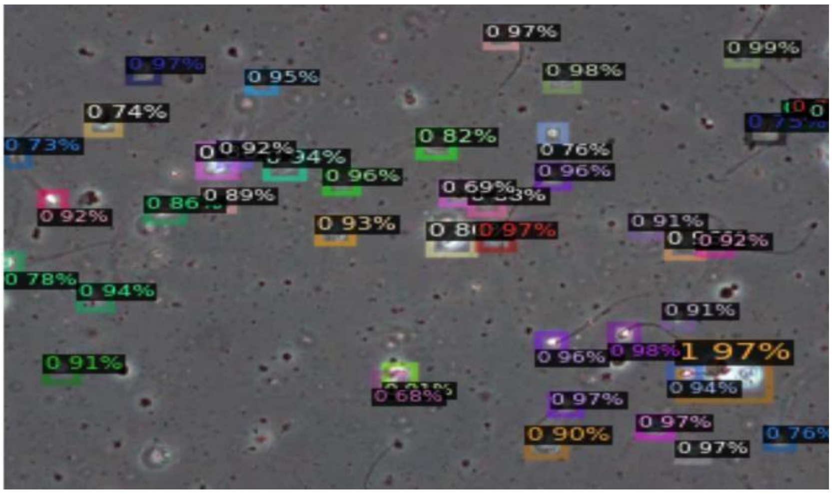

Fig-2: Sperm Detected

III. LITERATURE REVIEW

Sperm Detection and Tracking Using Modified CSR-DCF by Mohammadreza Mohammadi, Mohammad Rahimzadeh and Abolfazl Attar [1]

The research paper highlights the importance of accurately tracking sperm to gather valuable information for fertility studies. The authors propose modifying the CSR-DCF algorithm, originally designed for single-object tracking, to effectively track multiple sperm, even when they are close together or interacting in complex ways. For sperm detection, the Detectron2 deep learning model is employed, achieving high accuracies in detection tasks. A novel approach of feeding consecutive frames from videos to the neural network during training and testing is introduced, improving detection accuracy by extracting motion attributes of sperms. The modified CSR- DCF algorithm, along with additional algorithms like "Missing Tracks Joiner," facilitates sperm tracking with high accuracy. Key accuracies reported include an average precision of 99.1% for sperm detection and an F1-score of 96.61% for sperm tracking, evaluated against ground truth manual annotations.

VISEM-Tracking Dataset for Sperm Analysis by Vajira thambawita, Steven A. Hicks1, Andrea M. Storas, Oliwia Witczak2, Pal Halvorsen and Michael a. Riegler [2]

The paper addresses the challenge of manually assessing sperm movement by proposing the use of deep learning models. The authors introduce the VISEM-Tracking dataset, containing annotated video recordings of sperm samples, to fill the data gap required for effective machine learning. Baseline sperm detection is performed using the YOLOv5 deep learning object detection model, trained on different versions of the dataset. The YOLOv5l (large) model achieves the best performance, with a precision of 0.4323 and a recall of 0.2550. Various metrics such as precision, recall, mAP@0.5, and mAP@0.5:0.95 are reported, with the YOLOv5l model achieving a fitness value of 0.0920, calculated based on mAP scores.

Automated Tracking and Motility Analysis of Human Sperm by Leonardo F. Urbano, Puneet Masson, Matthew VerMilyea, and Moshe Kam [3]

This research introduces a fully automated multi-sperm tracking algorithm capable of detecting and tracking hundreds of sperm cells simultaneously in time-lapse microscopy videos. The algorithm accurately measures motility parameters over time with minimal user intervention.

The joint probabilistic data association filter (JPDAF) is adapted from radar tracking to automatically track and associate measurements to sperm tracks, even in challenging scenarios like close proximity or collisions. The algorithm continuously measures eight important sperm motility parameters, revealing temporal changes in motility that population statistics obscure. It demonstrates the capability to track sperm for longer durations compared to existing systems, achieving around 95% sperm detection accuracy with a low false detection rate.

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Bull Sperm Tracking and Motility Classification by Priyanto Hidayatullah1, Tati Mengko, Rinaldi Munir and Anggraini Barlian [4]

The paper proposes new techniques for tracking and classifying bull sperm, introducing concepts such as the "Tracking-Grid" method and machine learning-based classification algorithms. Mean accuracy of 92.08% is achieved for sperm motility classification using the BSPMC_svm3casa classifier, which outperforms other classification methods using static thresholds.

IV. METHODOLOGY

Object Detection with Detectron2: Utilize Detectron2, a deep fully convolutional neural network, for sperm detection in phase- contrast microscopy image sequences. Input a concatenation of frames to the network to capture motility attributes essential for fertility analysis.

Modified CSR-DCF Tracker: Adapt the CSR-DCF tracker, originally designed for single-object tracking, to handle multiple sperm tracking. Incorporate novel functionalities such as the "missing tracks joiner" to address false positives and false negatives in tracking results. Initialize the tracker on detected sperms in the first frame and track each sperm from frame to frame, assigning tracked sperms to detected ones based on proximity. Apply the "missing tracks joiner" algorithm to improve tracking accuracy and address tracking failures caused by false positives and false negatives.

V. CHALLENGES AND FUTURE DIRECTIONS

In developing our male fertility assessment approach using Detectron2 and CSR-DCF algorithms, challenges included data acquisition complexity and algorithm optimization. To address these, future efforts will focus on expanding datasets with varied semen sample videos, optimizing algorithms for efficiency, and collaborating with clinics for data access. Additionally, integrating genetic or hormonal markers and conducting clinical validation studies are crucial for real- world adoption. User-friendly tools and cloud-based platforms will enhance accessibility and impact in healthcare.

VI. CONCLUSIONS

The proposed advanced multi-object sperm tracking algorithm combines state-of-the-art object detection with a modified tracking algorithm to enable accurate and robust analysis of sperm behavior and fertility potential. By addressing challenges such as high-density samples, occlusions, and false detections, the algorithm demonstrates promising results in tracking accuracy and reliability. Future enhancements and integration with clinical tools hold the potential to further advance fertility analysis and reproductive health research.

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