



# Enhanced Sperm Image Segmentation Using MCFA Unet: Integrating Multi-Channel Feature Extraction and Attention Mechanisms

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#### Introduction/Background

The segmentation of sperm images is critical in the field of assisted reproductive technology (ART). Infertility affects millions globally, and male reproductive health plays a significant role in many of these cases. Sperm quality analysis has therefore become essential for evaluating male fertility. Accurate sperm segmentation is crucial as it enables automated sperm counting, morphological analysis, and motion tracking, significantly enhancing diagnostic accuracy and efficiency.

#### **Methods/Intervention**

In this study, we introduced an improved U-Net model, the Multi-Channel Feature Extraction U-Net (MCFA Unet), aimed at enhancing the precision and reliability of sperm segmentation. The U-Net architecture, well-known for its effectiveness in biomedical image segmentation, was adapted with several key enhancements: Multi-Channel Feature Extraction: This allows the model to capture a wider range of sperm characteristics, improving segmentation accuracy. Advanced Data Augmentation: By increasing the variety of training images, the model becomes more robust to different sperm image variations. Improved Loss Function: Combining Dice loss and cross-entropy loss ensures more precise segmentation. We trained and tested the MCFA Unet on subset B of the Sperm Video Image Analysis (SVIA) dataset, which provided a comprehensive set of annotated sperm images for robust evaluation.

#### **Results/Outcome**

Our experiments on subset B of the SVIA dataset showed that the MCFA Unet significantly outperformed traditional models in sperm image segmentation. The key performance metrics were: Dice Coefficient: 91.27, indicating a high overlap between the predicted segmentation and the ground truth. Jaccard Coefficient: 84.14, which measures the similarity between the segmented results and the actual sperm cells. These results demonstrate the high precision and reliability of the MCFA Unet model, attributed to its enhanced feature extraction capabilities.

### Conclusion

The MCFA Unet model offers a significant improvement in the precision and reliability of sperm image segmentation compared to traditional methods. This enhancement has substantial implications for the automation and accuracy of sperm quality analysis in ART, reducing the dependency on manual analysis and making the process faster and less error-prone.

#### **Statement of Impact**

By improving sperm segmentation accuracy, the MCFA Unet model contributes to better diagnostic tools in assessing male reproductive health.



Comparison of segmented results, (A) labels, (B) results, (C) results with false-negative false-positive results, (D) local magnification results



MCFA Unet network diagram

ISM/EI	Dice	Jaccard	Recall
U-net	78.89	65.16	83.93
SegNet	67.56	51.07	65.39
Deeplab_V3	78.34	64.41	84.96
MCFA Unet	91.27	84.14	90.9

Comparative table of results

## Keywords

Segmentation; Sperm Analysis; Attention Mechanisms; Attention Mechanisms; Deformable Convolutions