MetaSystems White Paper

AI-DRIVEN FORENSIC SPERM DETECTION

MetaSystems – Innovative Solutions for Automated Microscopic Imaging

Sperm cells are a crucial piece of evidence for solving sexual crimes and are usually detected by microscopy. The smart scanning solution by MetaSystems automates the search for sperm cells in forensic specimens. An advanced algorithm based on a Deep Neural Network (DNN) brings the advantages of artificial intelligence (AI) to forensic microscopy. Automation of microscopic imaging can contribute to shorten turnaround times in specimen examination.

Highlights

- Automated slide scanning replaces the lengthy and tedious manual search.
- Circa 15 to 20 minutes scanning time per slide with suitable specimen and hardware.
- Brightfield and fluorescence illumination for different staining types.
- Easy interactive review of spermatozoa with a convenient display of gallery images.
- Unattended slide scanning overnight possible.
- Storage of all object coordinates of detected sperm cells and quick relocation on the slide.
- Efficient transfer of object coordinates to laser microdissection systems.
- Standardized templates for reporting.
- Integrated case and image management.
- Integration to a LIMS is possible.
- Software add-on available for GLP compliance.

Automation Is Key to Reduce Backlogs

The labor-intensive and time-consuming search for sperm cells in forensic samples often represents a bottleneck in solving cases of alleged sexual assault. The result is an increasing backlog in many laboratories. A prominent example is the rape kit backlog in the USA. Sexual assault evidence kits, also informally called rape kits, are investigated in case of an alleged sexual assault. The materials of the rape kits are examined for the presence of spermatozoa and a DNA analysis is performed. The male DNA profiles are used to identify perpetrators and hold them accountable. The U.S. Government Accountability Office published a report in 2019, which found that the number of backlogged DNA analysis requests rose from about 91,000 to about 169,000 untested samples from 2011 to 2017 (GAO-19-216 *1). Scott Berkowitz, CEO and founder of the Rape, Abuse and Incest National Network

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(RAINN), was cited as follows in an article of The Washington Post: "I think the labs are doing a spectacular job, but they're drinking from a fire hose." (*2). To overcome this critical situation, the U.S. Department of Justice has released a publication on National Best Practices for Sexual Assault Kits (NCJ 250384 *3). One of the considerations listed in there is the incorporation of robotics and automation.

MetaSystems has more than 35 years' experience in automated slide imaging for medicine and life sciences. We provide a slide scanning solution to detect spermatozoa on microscope slides and offer automation technology on the microscopic examination of rape kits or vaginal swab smears. Automation can play a key role to keep up with increasing sample amounts. A fully motorized microscope can be operated with the Metafer software by MetaSystems.

For microscopic detection of spermatozoa in forensic samples, we have configured a scanning system operated by our Metafer software with the two illumination modes brightfield and fluorescence. Thus, the system supports three different staining techniques, i.e., Christmas Tree staining (Nuclear Fast Red/Picroindigocarmine), Baecchi stain (acid fuchsin and methylene blue), and commercial fluorescent staining kits. This allows you to process slides with different staining types on the same scanning system.

Artificial Intelligence Advances Microscopy Imaging

To detect spermatozoa stained with a fluorescent staining kit, e.g., Sperm HY-LITER™ (Independent Forensics *4), we use a machine learning approach. Developers configured an algorithm based on color, size, shape, and more features to detect sperm cells with a fully motorized microscope operated by our Metafer software.

In a study using mock sexual assault samples, human spermatozoa from vaginal swabs diluted 1:500 and mixed with blood, urine, and yeast were compared under manual observation and with a scanning system operated by the Metafer software. Spermatozoa counts agreed for 19 of 24 slides. Counts of three slides differed by only one spermatozoon. One slide had a difference of two spermatozoa and one slide had a difference of three spermatozoa (Moors and Frégeau, 2011 *5). The study concluded that for the used mock sexual assault specimens the automated detection of human spermatozoa was reliable and reproducible with the Metafer operated scanning system.

On popular customer demand, we implemented one of the latest advancements of artificial intelligence to sperm-staining techniques in brightfield: deep learning. While the principles of deep learning are decades-old, the recent availability of big data and computation power has pushed deep learning to a breakthrough. Deep learning is already in our everyday life, and you use it to unlock your phone with your face or to translate the menu in a foreign country's restaurant. Deep learning also pushes the frontiers in medicine and life sciences.

MetaSystems uses Deep Neural Networks (DNNs) to solve even the most difficult image processing tasks. Finding spermatozoa in forensic specimens is one such challenge. DNNs learn from example images that are labeled by experts. During training, a DNN self-optimizes its predictions by comparing the predicted image label to the actual label given by the expert ("ground-truth"). This supervised learning strategy also allows to continuously measure the training progress of the DNN. After complete training, the DNN is tested on a set of previously unseen images that was set aside before the training (around 5 % of data). Our fully trained DNN correctly classified 99 % (937 out of 946) of images showing spermatozoa stained with Christmas Tree staining. Usually, police and crime labs validate the Metafer operated scanning systems on their own and do not make validation data available for the

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public. However, we are happy to get you in touch with our existing customers.

Artificial Intelligence
Enables a machine to mimic human behavior

Machine Learning
Distinguishing features engineered by human developer

Deep Learning
Distinguishing features acquired by Deep Neural Network (DNN)
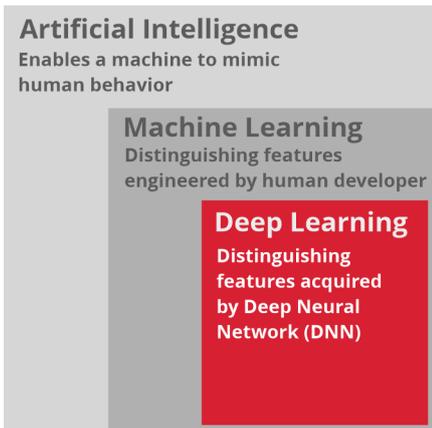
Figure 1: Deep learning is a subfield of artificial intelligence. A Deep Neural Network (DNN) optimizes its predictions by comparing the predicted image label to the actual label given by the expert. In this way, a DNN finds useful features for image discriminations without human interaction.

The software module Metafer Sperm-Finder DNN can process forensic specimens stained with "Christmas Tree" (Nuclear Fast Red/Picroindigo-carmine) or Baecchi (Acid Fuchsin/Methylene Blue) staining in brightfield illumination. A typical slide is scanned in 15 to 20 minutes. The software stores object coordinates of detected sperm cells and allows for easy relocation of cells on the slide. A suitable graphics card is required for DNN-based calculations.

Slide Capacity is Scalable to Specific Demands

Systems operated with our Metafer software can be configured to meet the requirements of laboratories of different sizes. Different add-ons are available for small, medium, and large laboratories. If capacity requires 24/7 microscopy operation with the ability to prioritize urgent slides, we can provide an automated slide loader to feed the microscopic system. This allows for unattended slide scanning overnight or on weekends. With a scalable capacity from 8 up to 800 slides being automatically scanned, we support our customers in high-throughput applications.

Forensic Starch Particle Detection

One way to prove that a condom was used in a sexual assault is to detect starch particles using light microscopy. Most latex condoms are coated with a thin layer of corn starch to prevent the latex sticking to itself, which makes the condom easier to unroll. When polarized light is used, the starch granules show the typical "Maltese cross" birefringence pattern when examined under the microscope.

Our colleagues are currently working on the incorporation of artificial intelligence to support the detection of starch granules in an automated microscope solution. Thereby, the detection of starch granules is a promising addition to the AI-based sperm detection in forensic samples that we already offer.

Want to Know More?

MetaSystems offers innovative solutions for automated microscopy imaging for numerous applications with brightfield and fluorescence illumination.

Would you like to know more about how MetaSystems uses artificial intelligence? Please contact us at **info@metasystems.ai**.

This method is for Research Use Only and not to be used in diagnostic procedures.

Sources

*1 GAO-19-216; United States Government Accountability Office, Report to Congressional Requestors, Title: DNA Evidence DOJ Should Improve Performance Measurement and Properly Design Controls for Nationwide Grant Program; March 2019.

*2 The Washington Post, 03/23/2019, https://www.washingtonpost.com/crime-law/2019/03/23/nationwide-dna-testing-backlog-has-nearly-doubled-despite-billion-federal-funding/

*3 NCJ 250384. The National Institute of Justice is the research, development and evaluation agency of the U.S. Department of Justice. Title: National Best Practices for Sexual Assault Kits: A Multidisciplinary Approach.

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*4 Sperm HY-LITER™ (Independent Forensics, Illinois, USA).

*5 A. De Moors, C. Frégeau, Forensic Science International: Genetics Supplement Series 3 (2011) e35-e36.

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