Resource-Efficient Nanoparticle Classification Using Frequency Domain Analysis

Mikail Yayla, Anas Toma, Jan Eric Lenssen, Victoria Shpacovitch, Kuan-Hsun Chen, Frank Weichert, Jian-Jia Chen

Department of Computer Science TU Dortmund
Leibniz-Institute for Analytical Science ISAS e.V., Dortmund

March 19, 2019

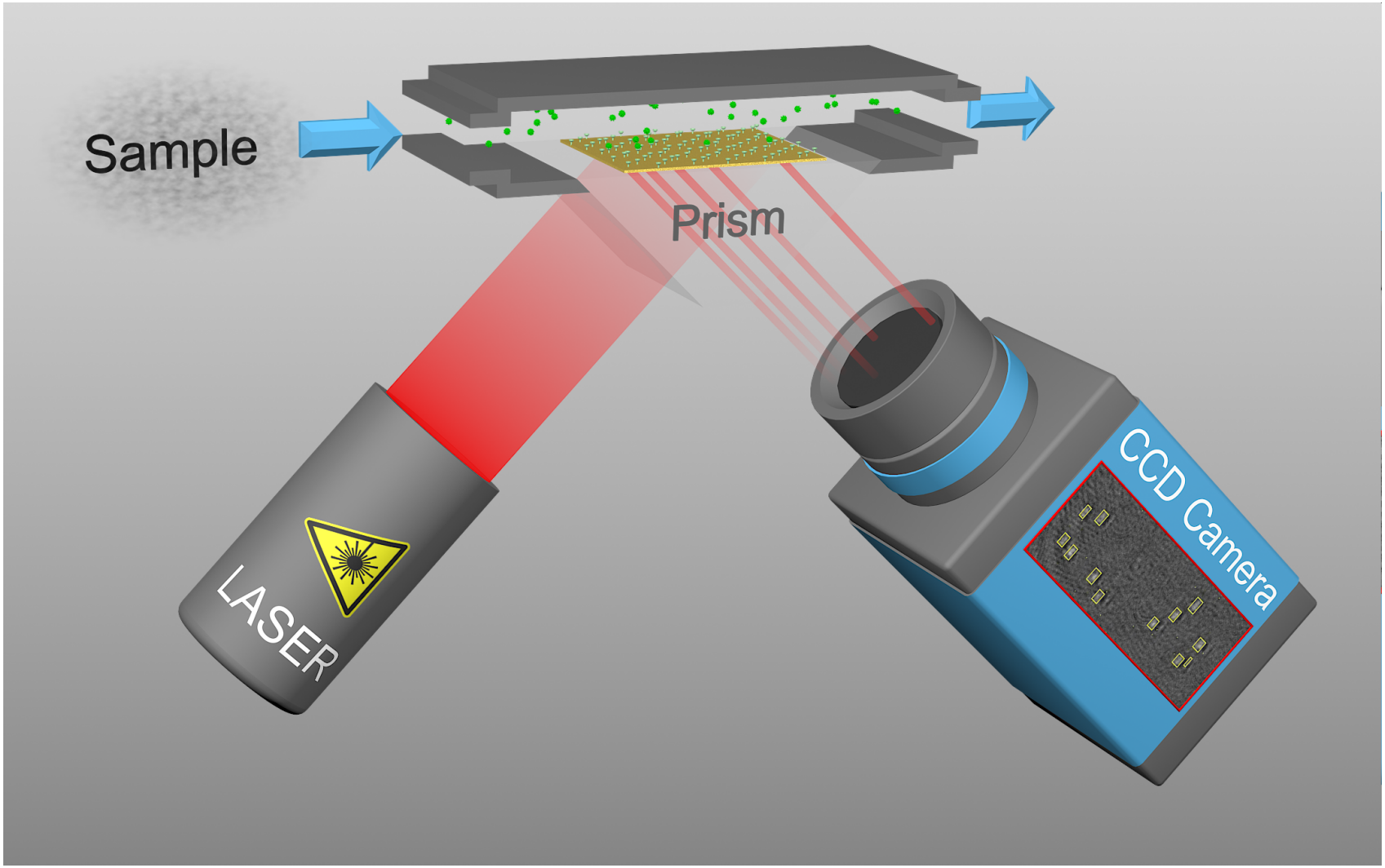
This research has been supported by DFG, as part of the Collaborative Research Center SFB876 subproject B2.

The Vision: A Mobile Virus Detection Device

Requirements of a mobile virus detection device

- Real-time virus detection
- High reliability
- Small size, portable handheld
- Low energy consumption
- Usage anywhere

PAMONO Biosensor



Plasmon-based Virus Detection on Heterogeneous Embedded Systems, Neugebauer et. al, SCOPES 2015

PAMONO Biosensor Setup

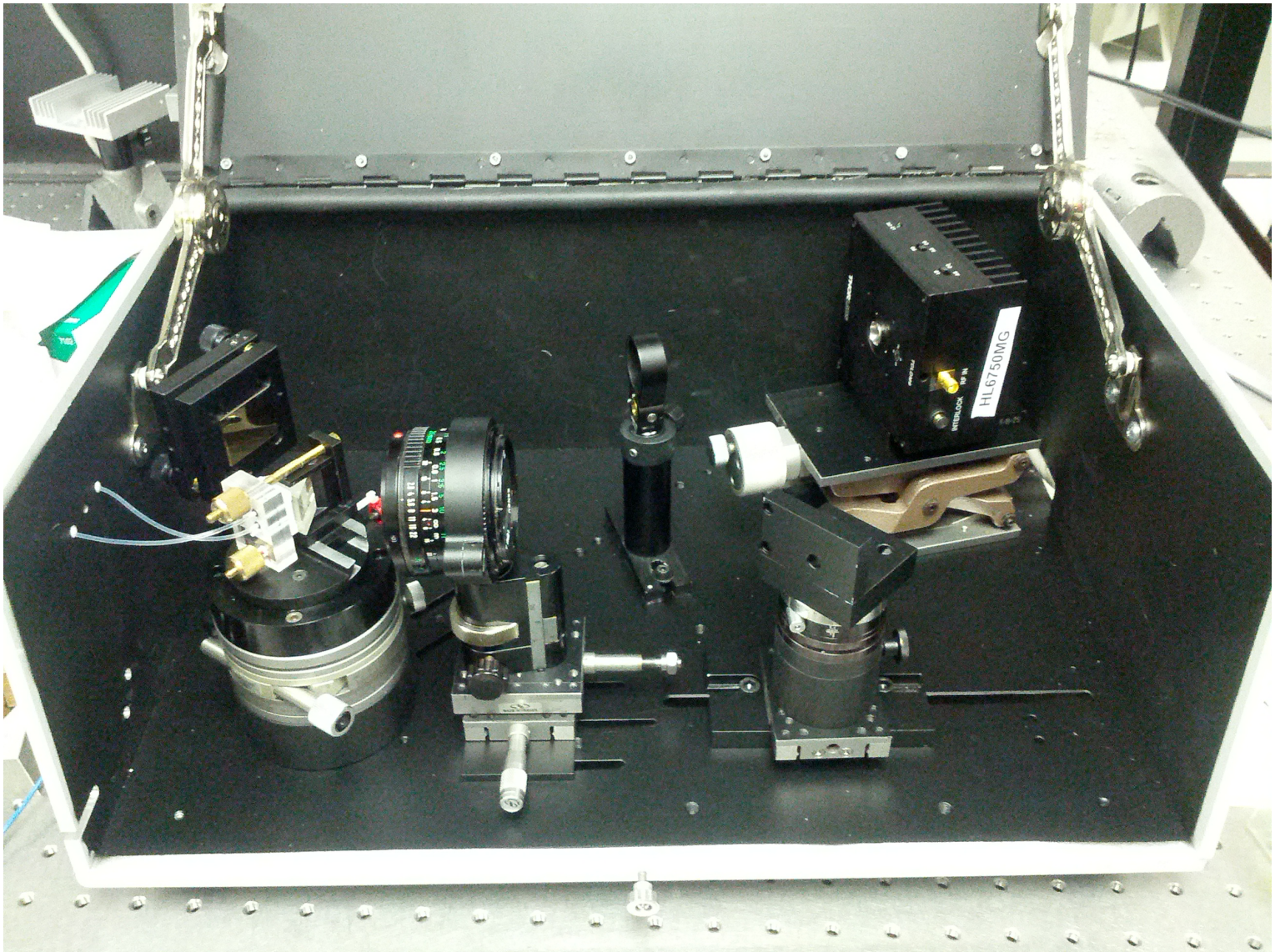
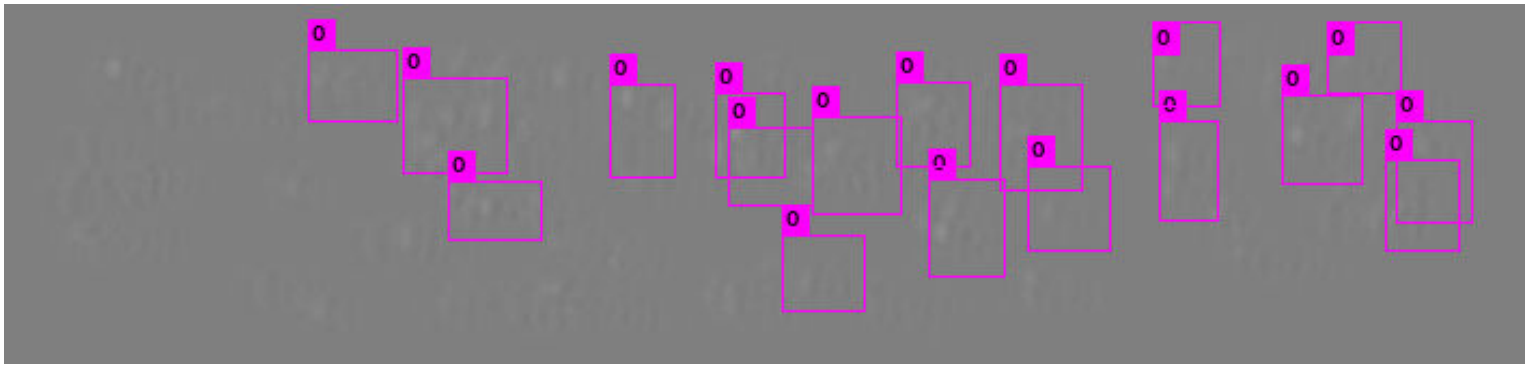
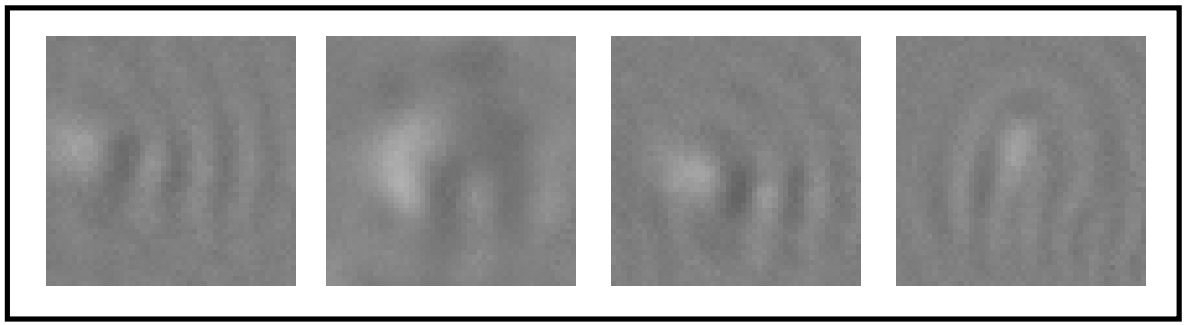
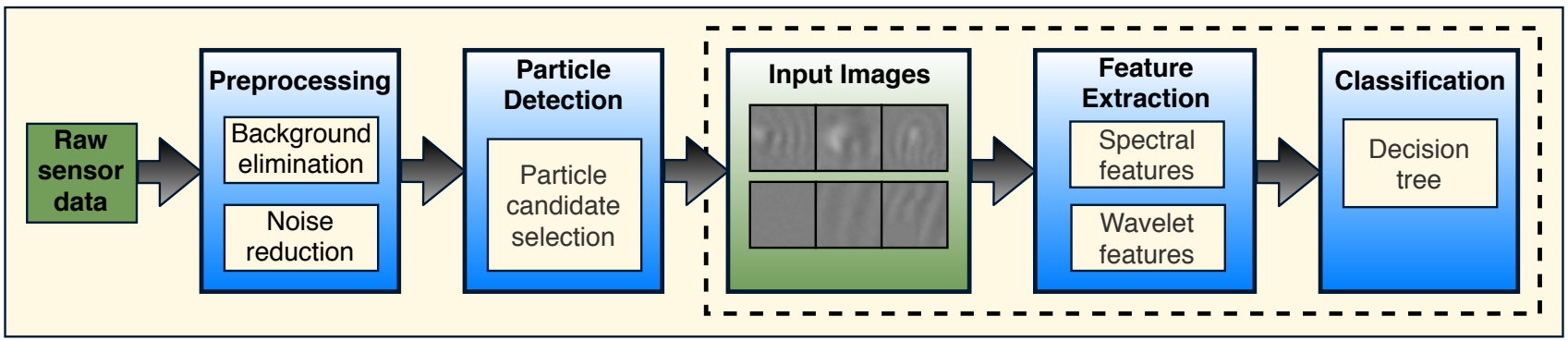


Image Processing Pipeline







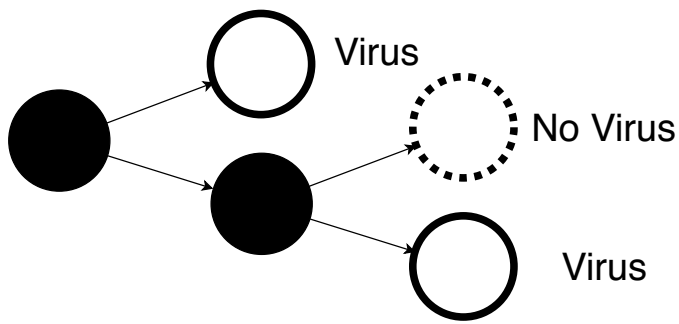
Virus Classification Methods

State-of-the-art: CNN based Methods exist, but...

- High resource demands: execution and training
- Mobile devices: no low power solutions

Frequency Domain Analysis

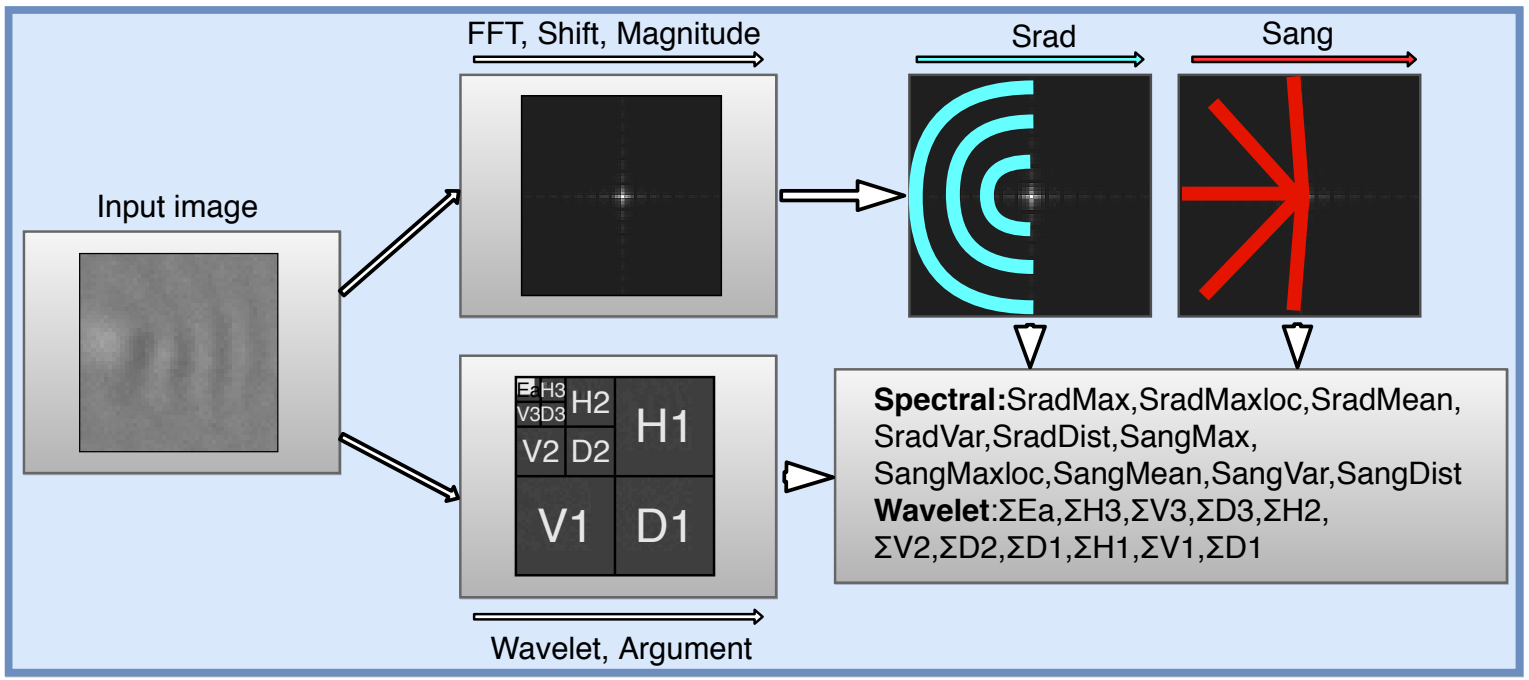
- Feature Extraction
  - Ubiquitous and resource-optimized
  - Algorithms and hardware: well-developed
- Classification: Decision Trees (DTs)
  - Efficient on embedded hardware
  - Execution time: few nanoseconds



Feature Extraction: FFT and FWT

Examples of Frequency Domain Analysis Methods

- Fourier transform based features
- Haar-wavelet transform based features



Results: CNN vs. Frequency Domain Analysis

Features	Measure	DT (%)	RF10 (%)
Both	Precision	98.49	99.33
	Recall	97.04	97.19
Only spectral	Precision	97.78	98.50
	Recall	96.33	96.02
Only wavelet	Precision	96.77	97.59
	Recall	96.35	96.63

Method	Execution time	Accuracy (%)
Spectral features	~~1.28 ms~~ 27μs	97.07
Wavelet features	~~1.50 ms~~ 17μs	96.57
Spectral and wavelet	~~2.78 ms~~ 44μs	97.78
CNN	3.37 ms	99.50

Conclusion

Takeaways

- Frequency Domain features with Decision Trees
- Trade-off: resource-efficiency and accuracy

Future Work

- 17 - 27 μs for CPU-only classification
- More patches can be classified
- Explore efficient methods for detection stage

Example Classification Errors

The classification has problems with:

- Weak bloblike excitations (FN)
- Strong wavelike excitations (FP)
- Signal errors and vibrations