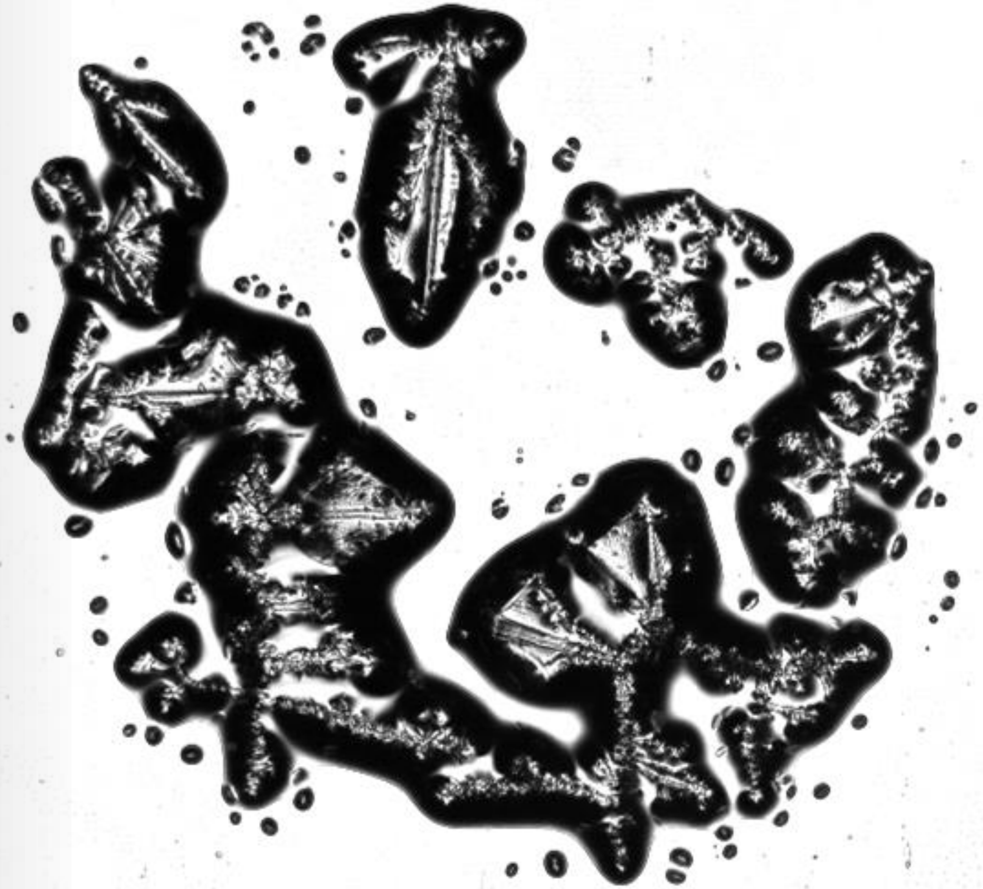
Pee Stain Pathology

Emily Gillott
Joseph Fishwick

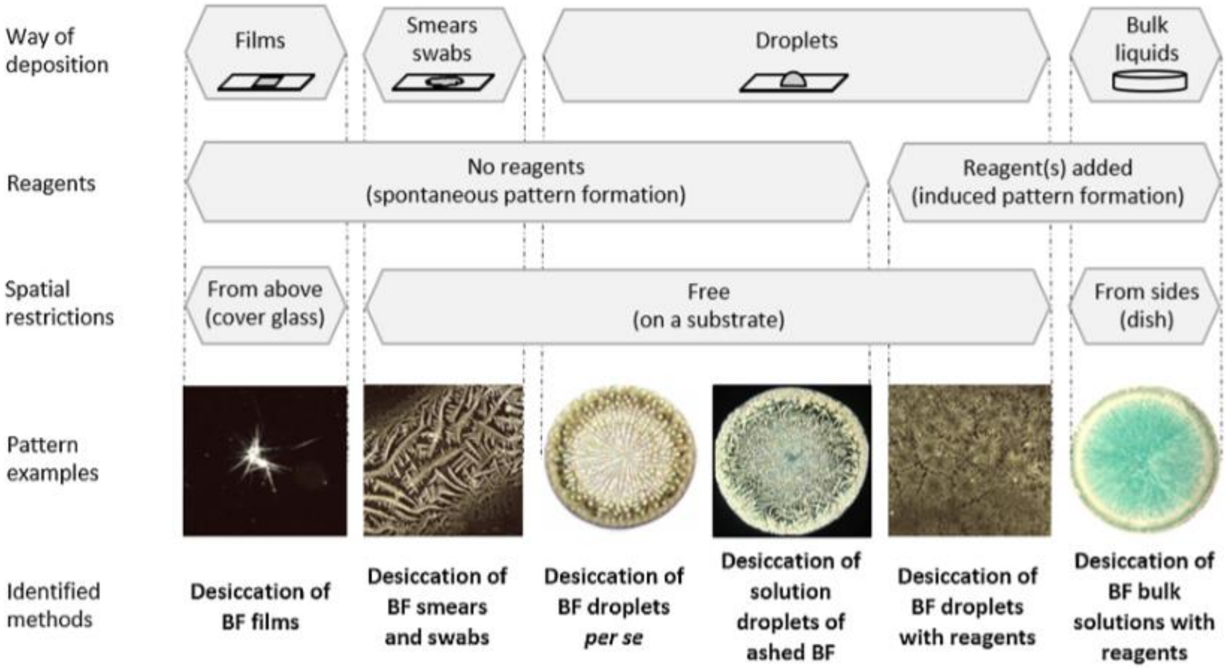


Desiccation Pattern Diagnostics

Dried droplets of various body fluids used as diagnostic tool for many diseases

Most use visual inspection for classification

ML classification have been applied to blood diagnosis, not much for urine.

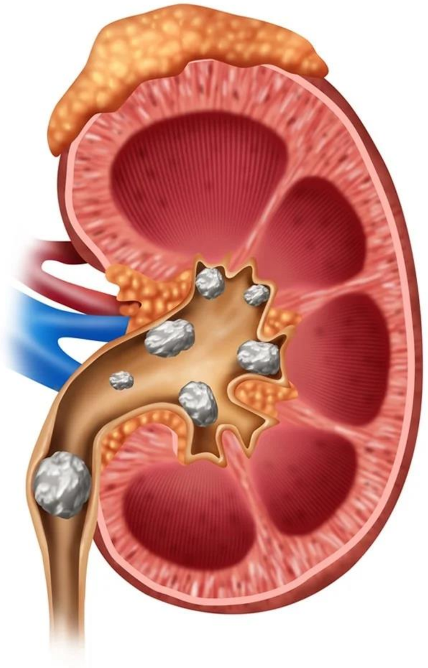


[Diagnostic tests based on pattern formation in drying body fluids – A mapping review | Elsevier Enhanced Reader]

Urological diseases

Diseases in urinary tract can alter composition of urine

- Kidney stones contain CaC_2O_4
- Kidney failure, cystitis, pregnancy issues release albumins



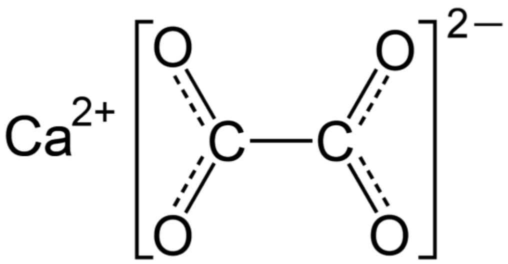
Project Aims

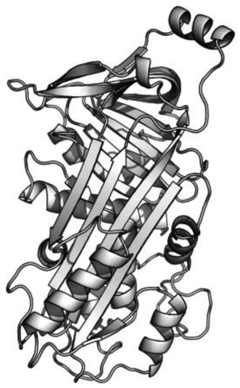
Test & compare different image classification models to be used for urological diagnostics.

Models used to detect high concentrations of disease biomarkers in dried samples of artificial urine.

Biomarkers used in study:

- Calcium oxalate CaC_2O_4
- Ovalbumin



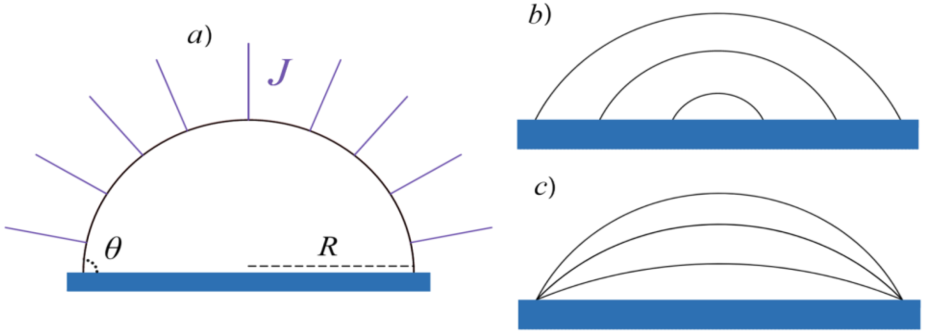


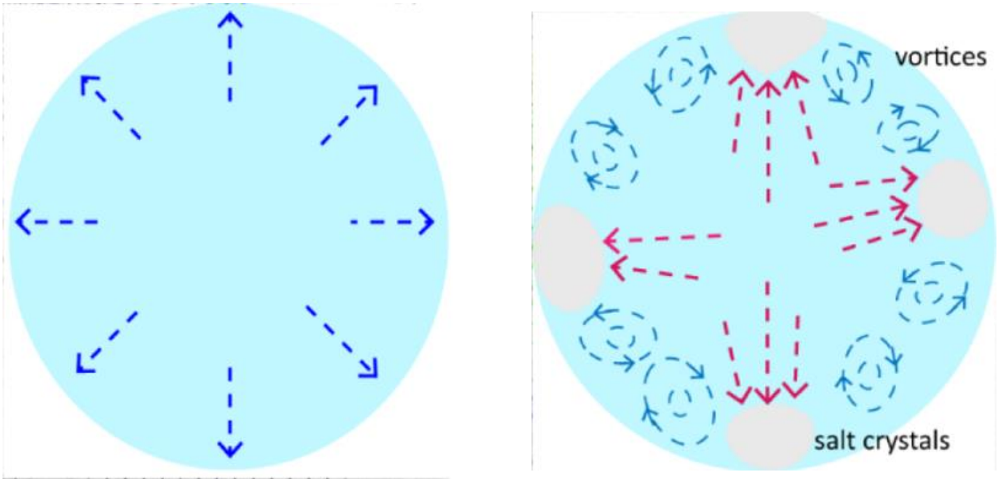
Physics of Drying Droplets

Diffusion limited model

Modes of evaporation

Capillary and crystallisation driven internal flows





[Dynamics of droplet drying -Crystallization-Driven Flows within Evaporating Aqueous Saline Droplets |]

Desiccation patterns

Capillary flow advect and deposit particles to the drop perimeter, coffee ring effect.

Key patterns:
 - Crystallisation of salts
 - Cracking of protein gels

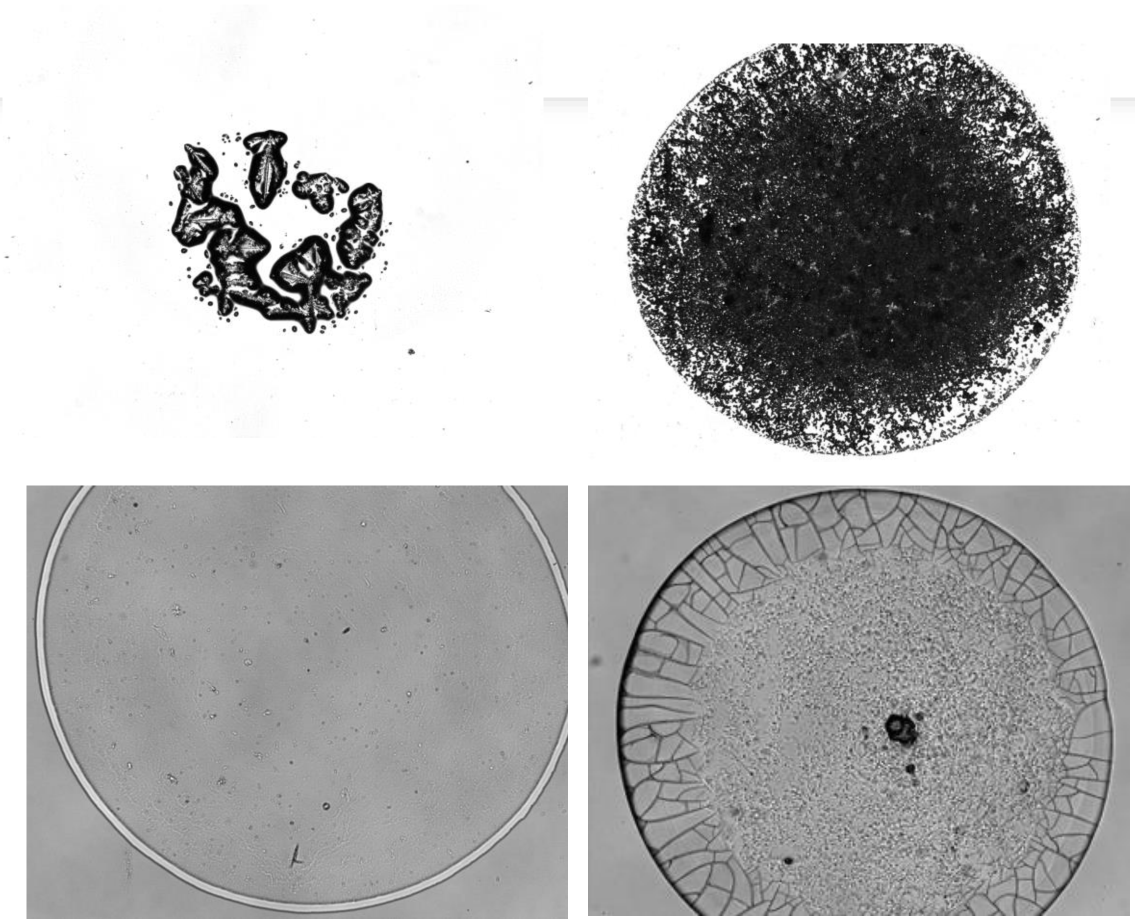
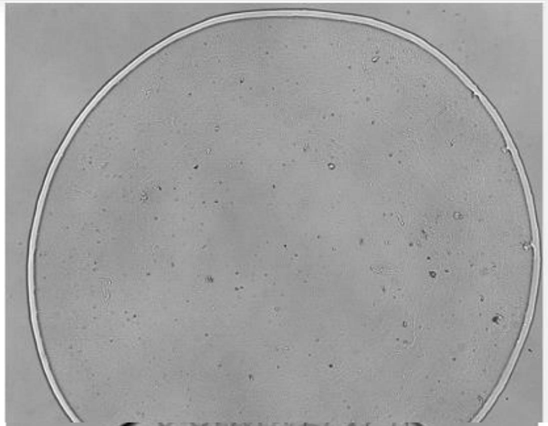


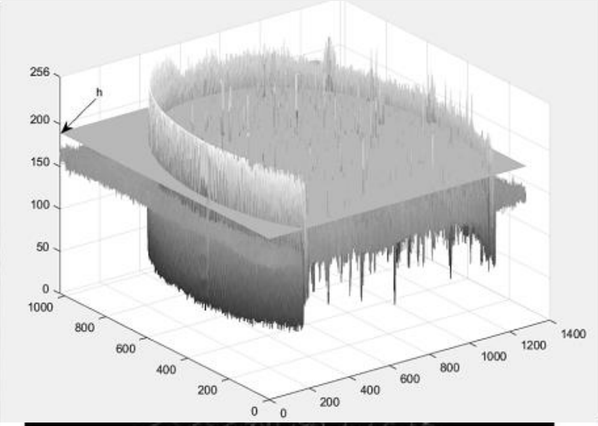
Image Processing

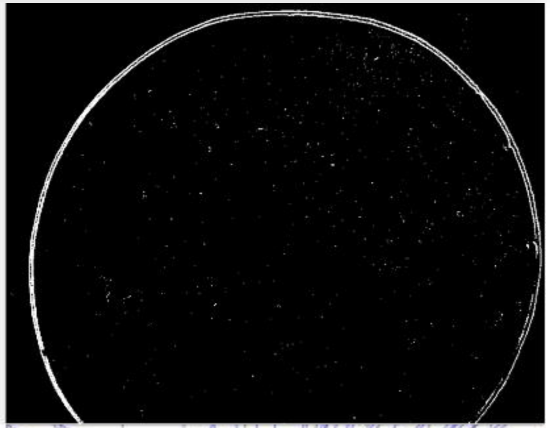
Raw image

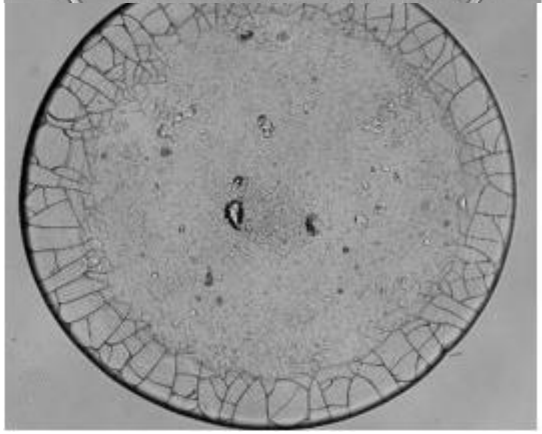
Minkowski analysis

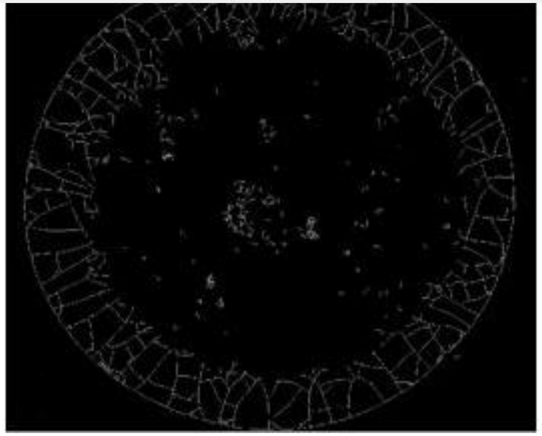
Voronoi analysis

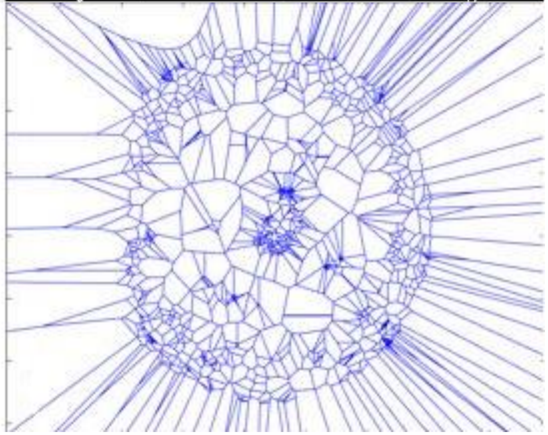












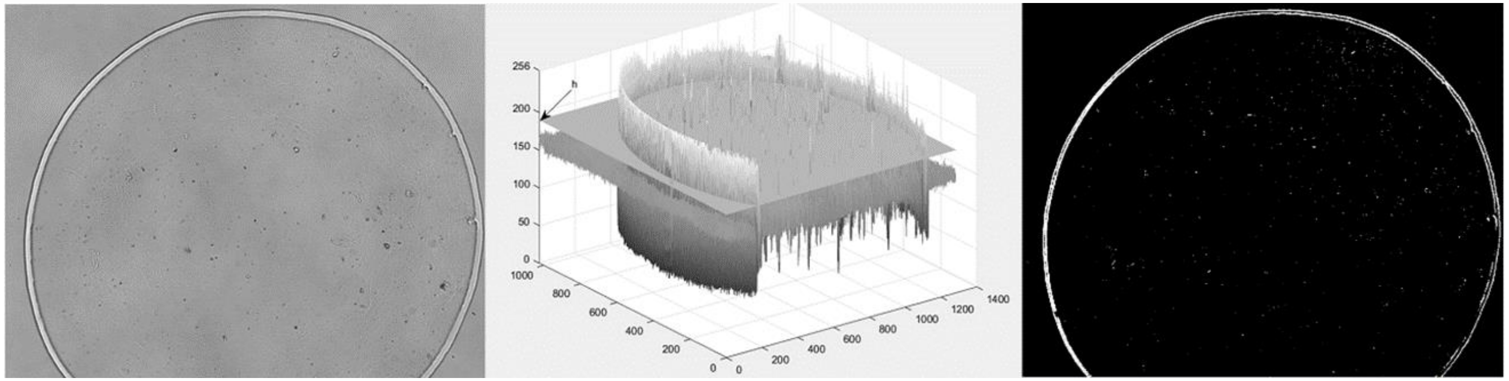
Minkowski Analysis

Minkowski functionals: A, P, χ

Scan image binarise threshold

Marching matrix calculation of functionals

Functionals normalised then concatenated to a "Minkowski signature"



$$Q_1 = \begin{pmatrix} 1 & 0 \\ 0 & 0 \end{pmatrix} \quad Q_2 = \begin{pmatrix} 1 & 0 \\ 1 & 0 \end{pmatrix} \quad Q_3 = \begin{pmatrix} 1 & 1 \\ 1 & 0 \end{pmatrix}$$

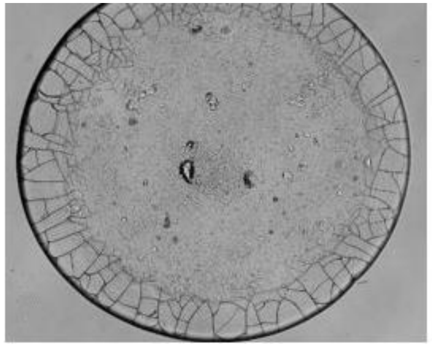
$$Q_4 = \begin{pmatrix} 1 & 1 \\ 1 & 1 \end{pmatrix} \quad Q_D = \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix}$$

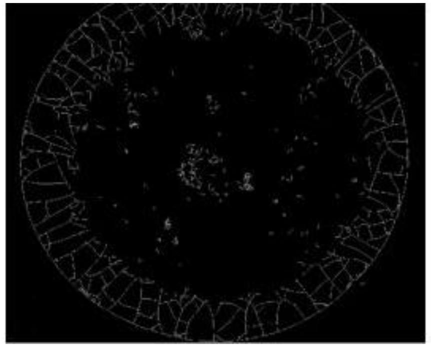
Voronoi Analysis

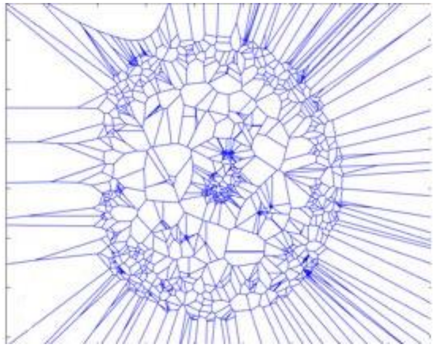
Extract crack skeleton, find branch points, seed Voronoi mosaic

Parameters extracted from Voronoi mosaic:

- Number of nodes
- Number of vertices
- Angular defect
- Isoperimetric ratio





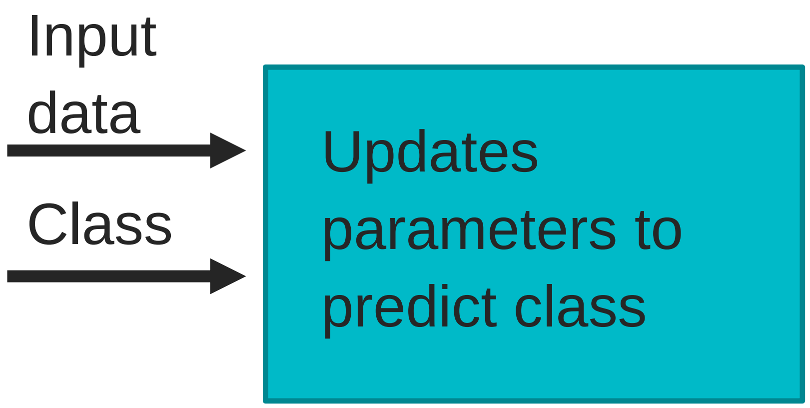


$$D = \frac{1}{\sum_i^v |\theta_i - \frac{(v-2)\pi}{v}| + 1}$$

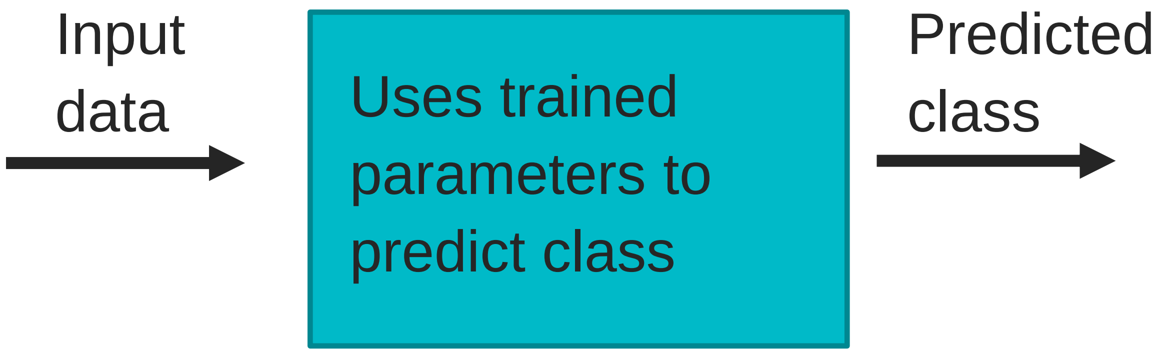
$$\lambda = \frac{4\pi A}{L^2}$$

Machine learning

Training:



Testing:



Metrics

Accuracy

$$A = \frac{TP+TN}{TP+TN+FP+FN}$$

Precision

$$P = \frac{TP}{TP+FP}$$

Recall

$$R = \frac{TP}{TP+FN}$$

<table>
<tr><td colspan="2" rowspan="2">Total population: TP+FN+FP+TN</td><td colspan="2">Predicted class</td></tr>
<tr><td>High conc</td><td>Low conc</td></tr>
<tr><td rowspan="2">Actual class</td><td>High conc</td><td>TP</td><td>FN</td></tr>
<tr><td>Low conc</td><td>FP</td><td>TN</td></tr>
</table>

Machine Learning Models

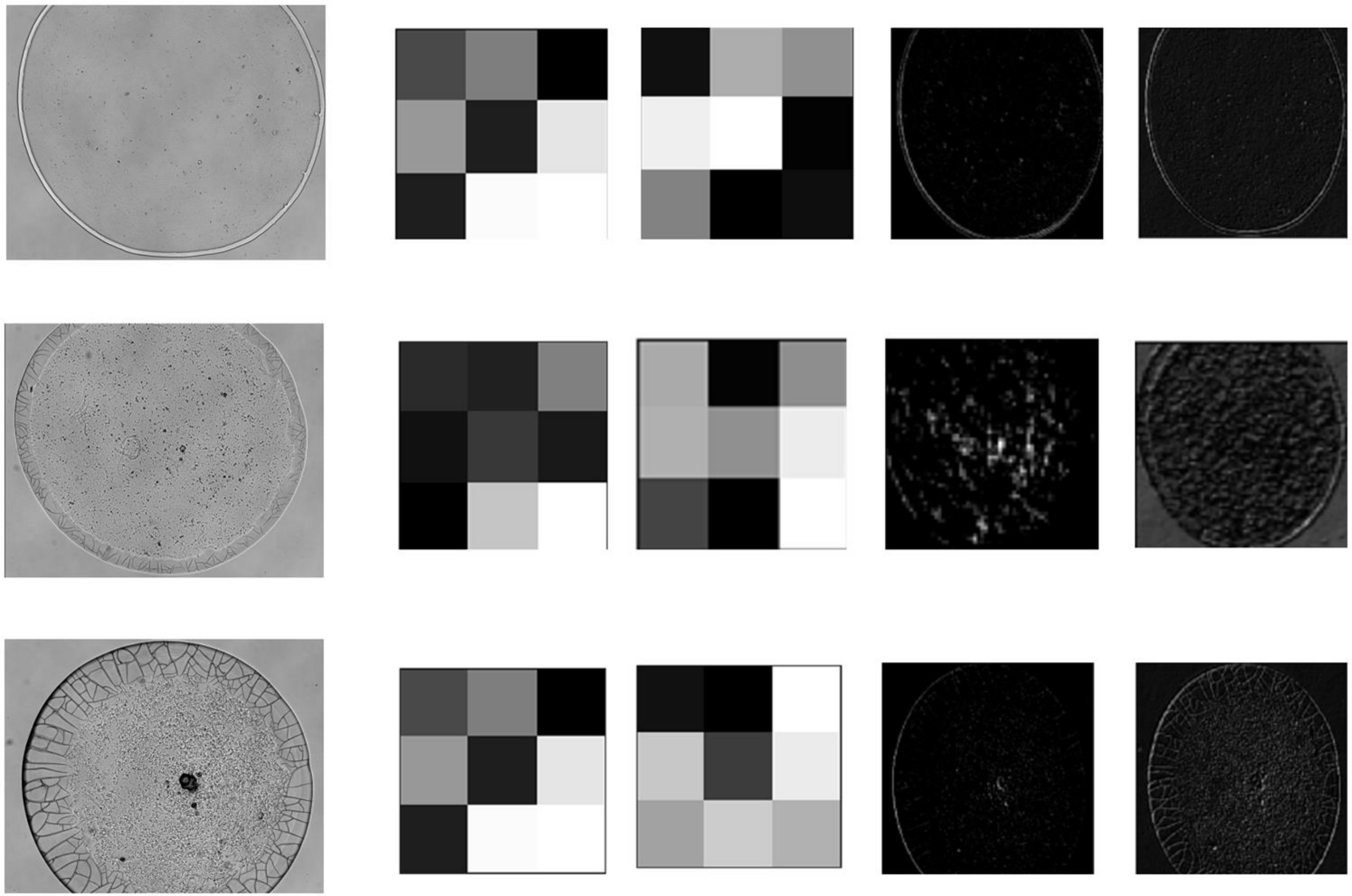
Neural networks vs non-neural networks

Raw image data vs image mined data

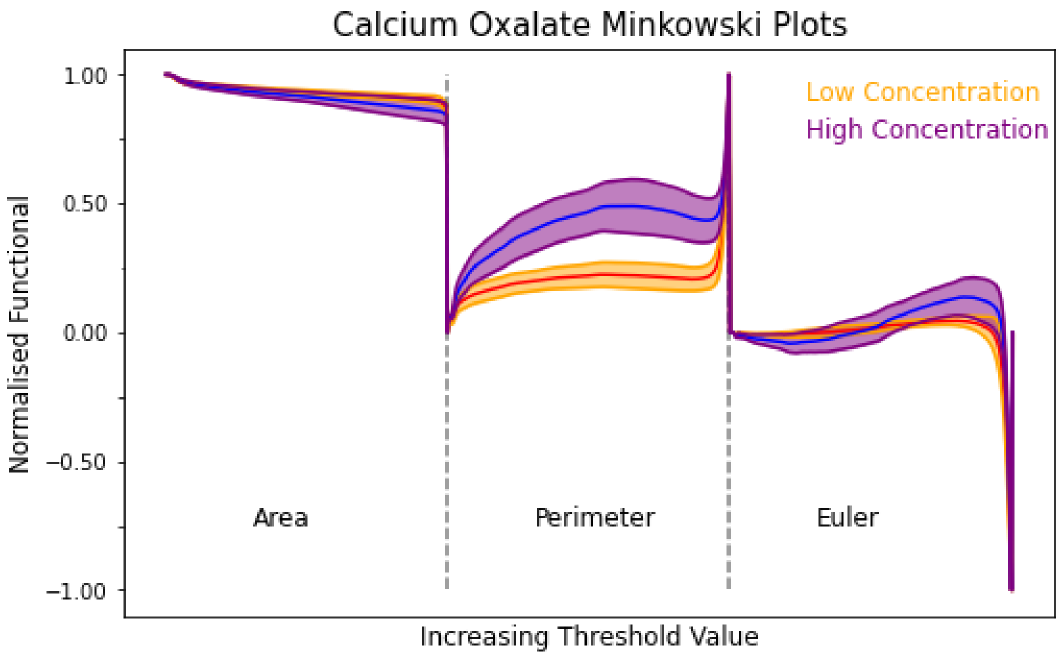
Neural Networks
- CNN
- Raw NN
- Voronoi NN
- Minkowski NN

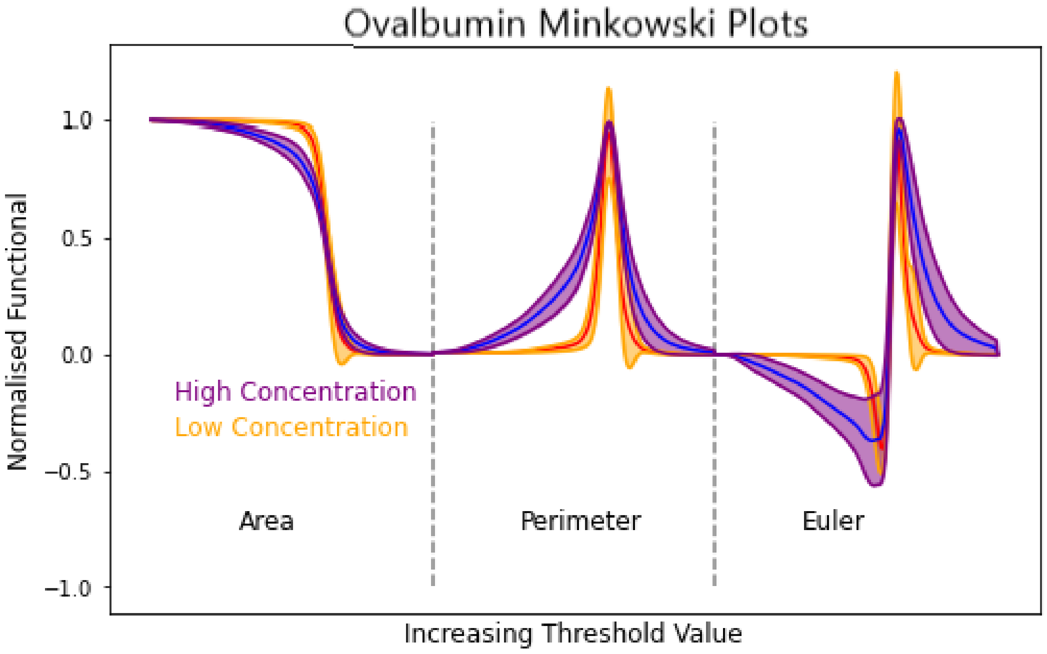
Non-NN
- Voronoi logistic regression
- Voronoi k-nearest neighbours

CNN Results

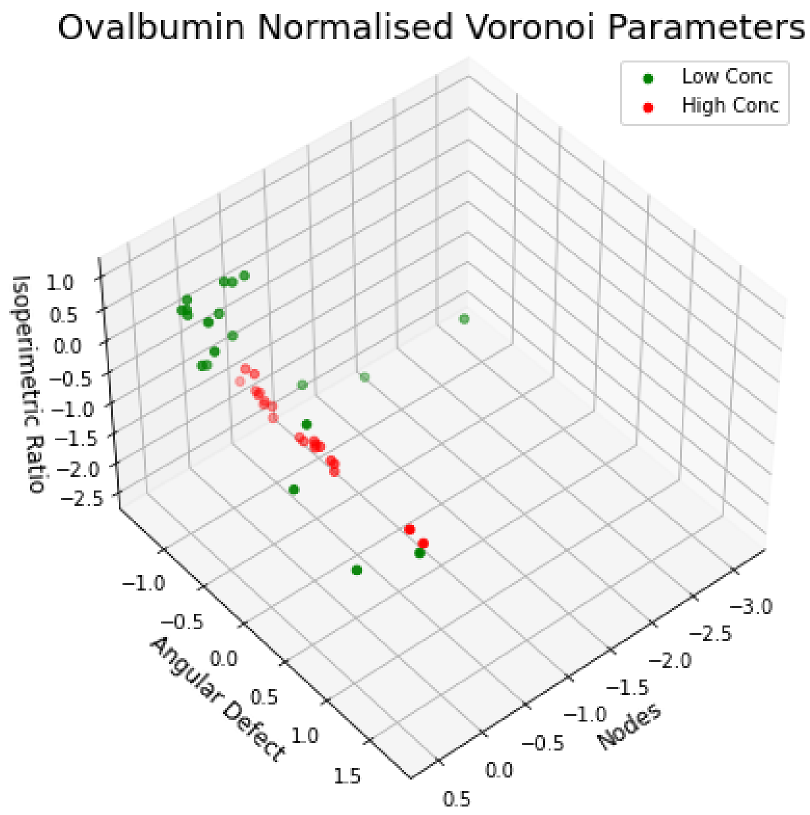


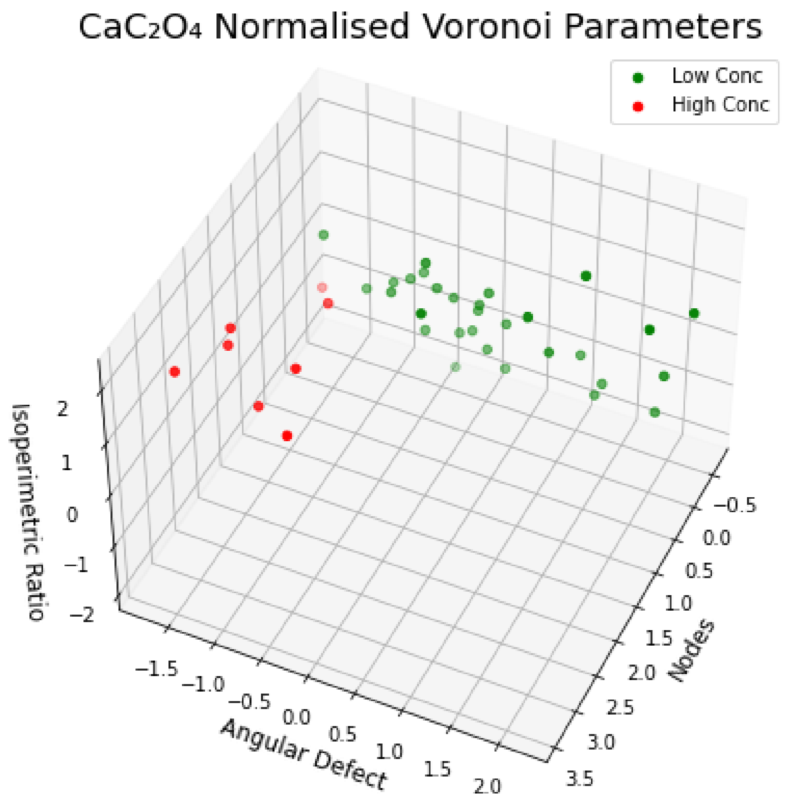
Minkowski Analysis Results



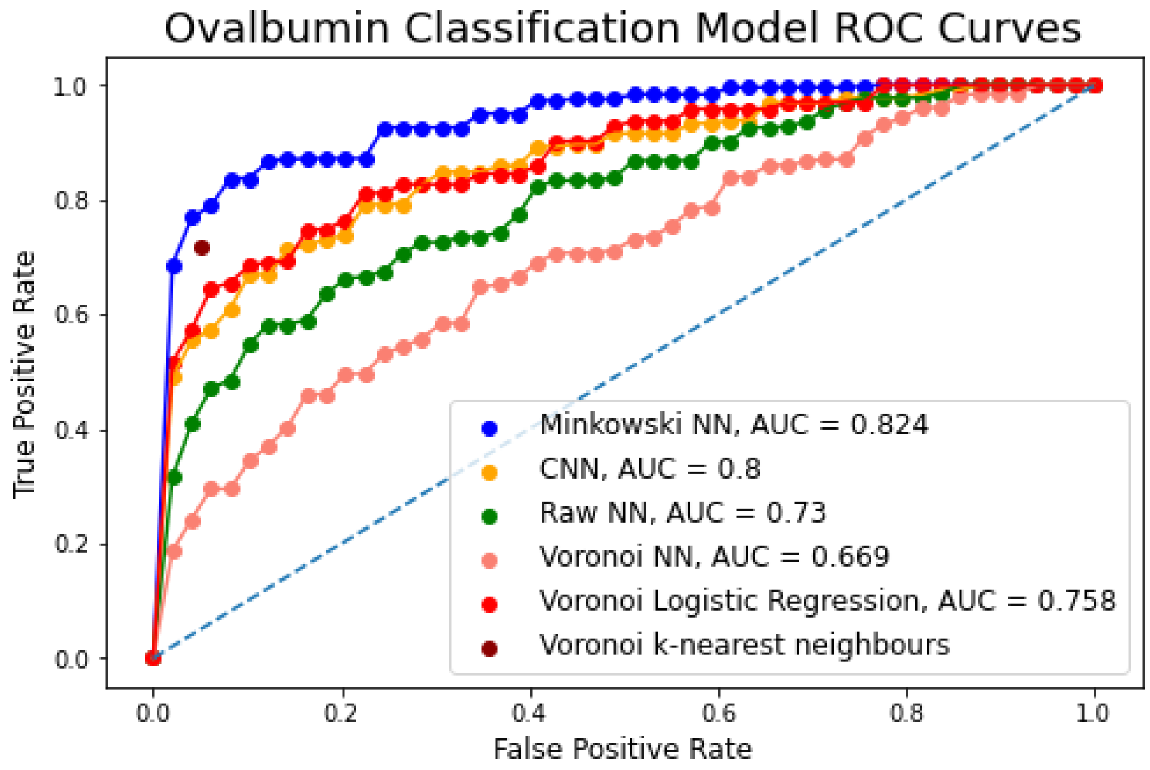


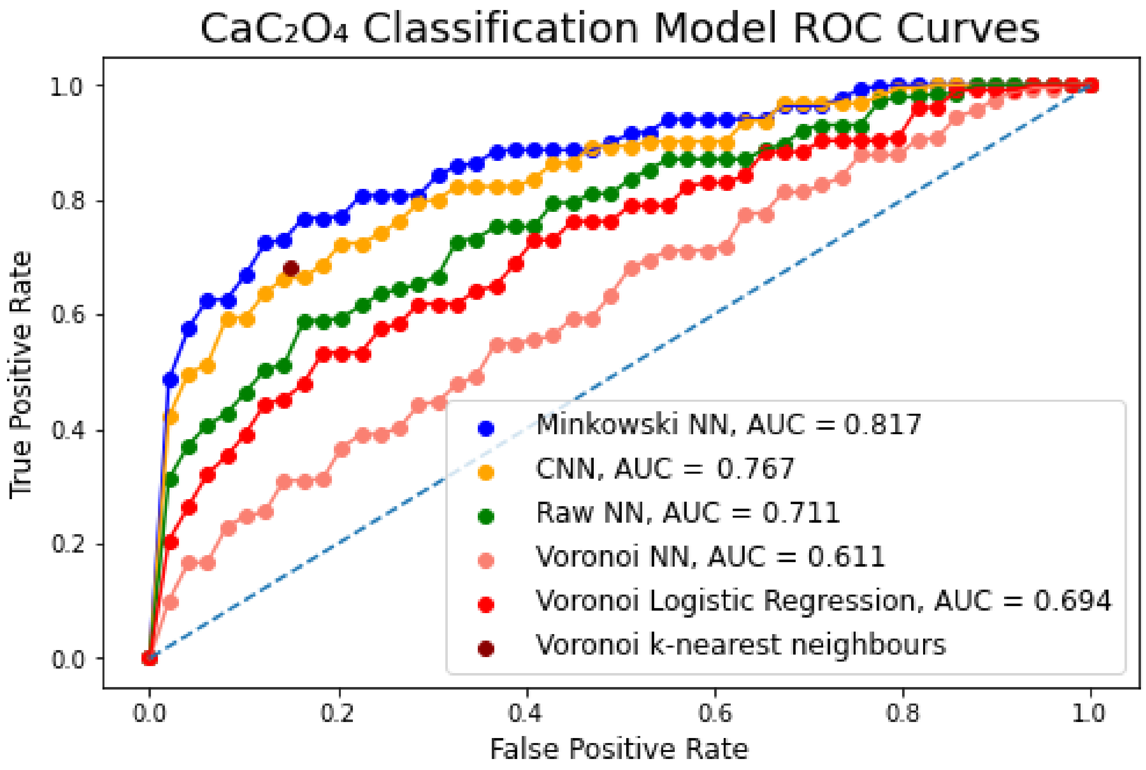
Voronoi Parameters Results





Model Comparison





Calcium oxalate results

Model	Accuracy	Precision	Recall
NN	0.697	0.692	0.728
CNN	0.755	0.824	0.724
Minkowski NN	0.799	0.855	0.768
Voronoi log reg	0.451	0.723	0.412
Voronoi NN	0.391	0.660	0.311
K means	0.563	0.853	0.540

Ovalbumin results

Model	Accuracy	Precision	Recall
NN	0.709	0.855	0.662
CNN	0.783	0.769	0.792
Minkowski NN	0.873	0.879	0.868
Voronoi log reg	0.521	0.785	0.812
Voronoi NN	0.521	0.652	0.647
K means	0.671	0.829	0.623

Discussion

- Model urine
- Tweaking within models, vary architectures
- Overfitting issues

Conclusions

- Neural networks outperformed non neural networks

- Minkowski analysis was optimal, closely followed by CNN

- Models performed better at protein detection than salt detection