# Classification of Wood Pulp Fibre Cross-sectional Shapes

Asuka Yamakawa
Norwegian University of Science of Technology
Gary Chinga-Carrasco
Paper Fibre Research Institute

# Outline

- ✓ Introduction
- ✓ Image Acquisition
- ✓ Classification Procedures
- ✓ Shape Descriptors
- ✓ Discriminant Analysis
  - Mahalanobis Discriminant analysis (MLDA)
  - Canonical Discriminant analysis (CDA)
- ✓ Results
- ✓ Future work and Conclusions

# Introduction

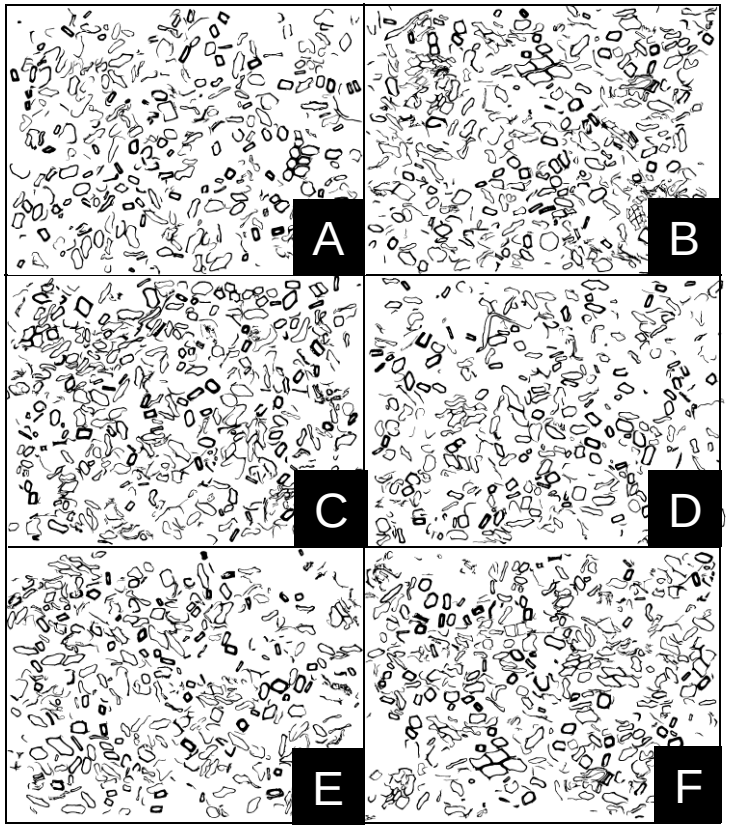
- ✓ Wood pulp fibres are in the spotlight within several industrial sectors, e.g. paper products, fibre-reinforced composite and as a source of raw materials for bio-energy and biochemicals production.
- ✓ Proper characterization of fibres is thus necessary.
  - ➡ Scanning electron microscopy (SEM) is suitable for assessment of cross-sectional dimensions of wood pulp fibres.
  - ➡ The quantification is time-consuming.
- ✓ Computerized image analysis is a powerful tool for the automatic quantification of wood pulp fibre dimensions.
  - ➡ The main challenge is not the automatic editing but the identification of a given fibre that may need a specific editing.
  - ➡ Two discriminant analyses are applied for the fibre classifications.

# Image Acquisition

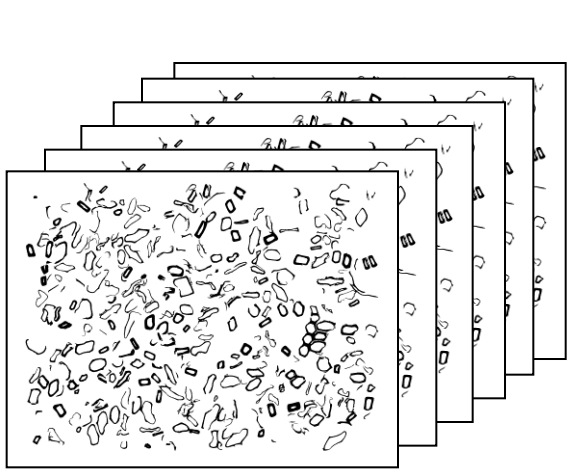
Market thermo-mechanical pulp (TMP) fibres

- ✓The fibres were aligned and freeze-dried.
- ✓They were embedded in epoxy resin and cure for 24hrs.
- ✓The blocks were hand-held ground and automatically polished.

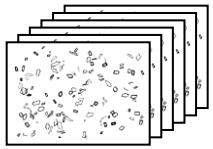
Magnification : 150x
Size of the image : 2560 x 1920 pixels
Resolution : 0.31 µm
Working distance : 8 - 10mm
# of objects : about 2000



# Classification procedure

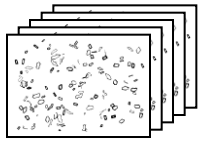


6slides



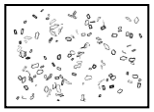
No lumen
(6slides)

=

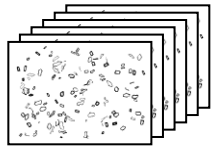


Teaching data
(5slides)

+



Checking data
(1slide)



Single lumen
(6slides)

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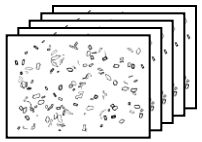

Teaching data
(5slides)

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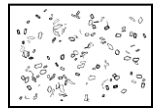
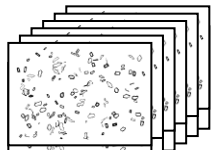


Checking data
(1slide)



Multiple lumens
(6slides)

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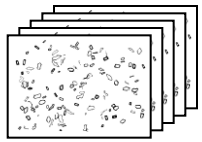

Teaching data
(5slides)

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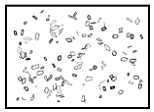
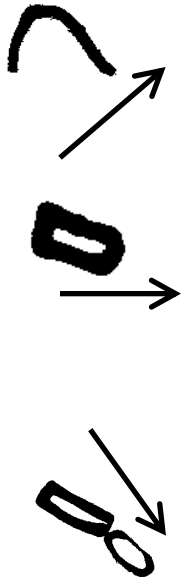
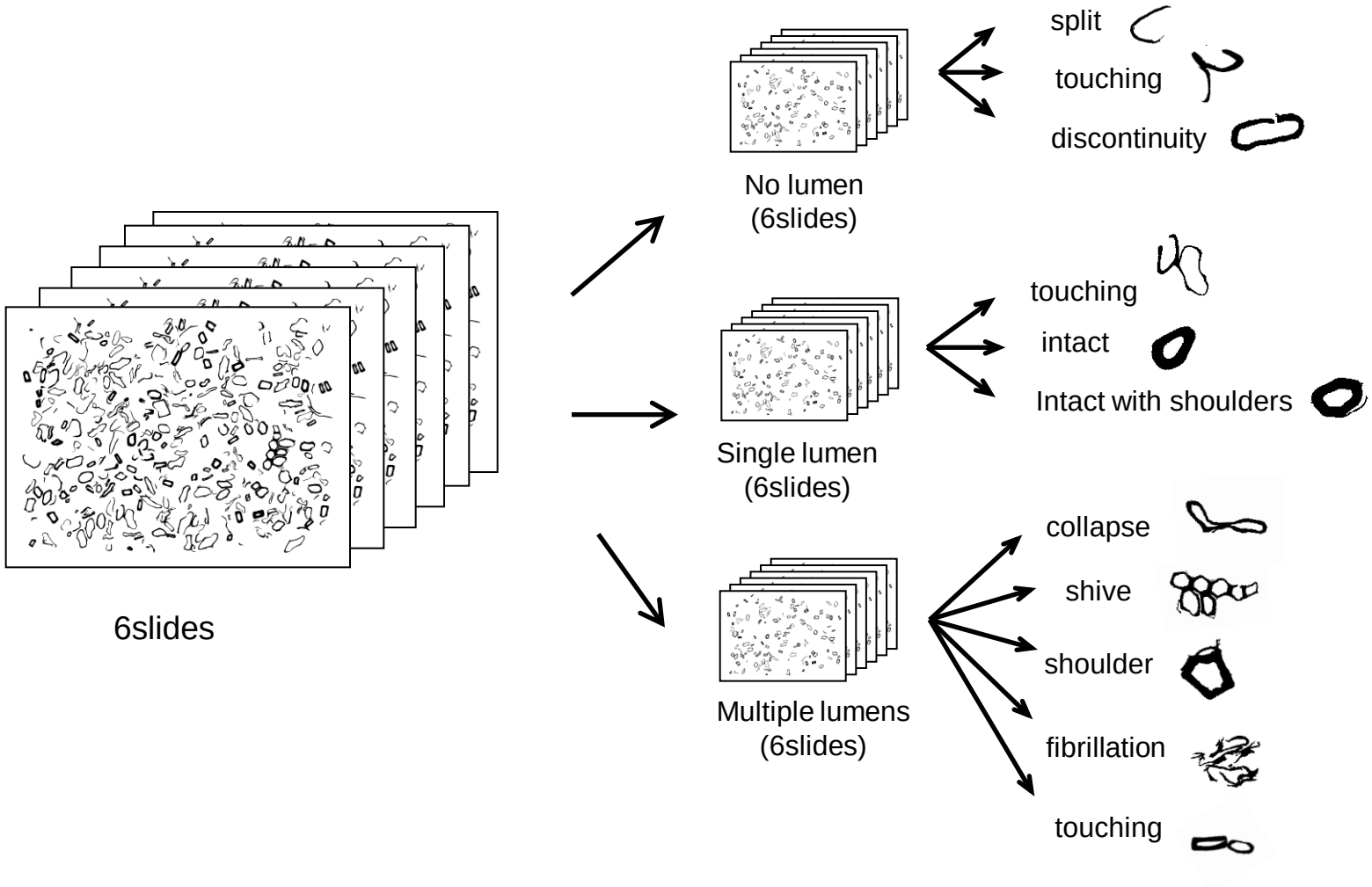


Checking data
(1slide)

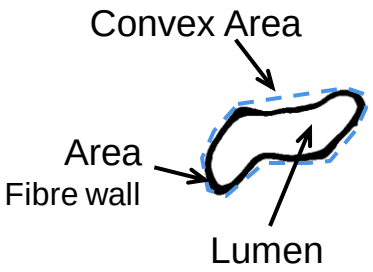


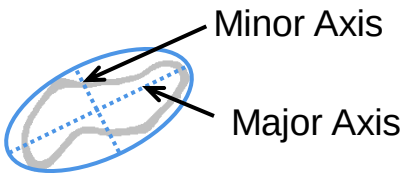
# Classification procedure



# Shape Descriptors

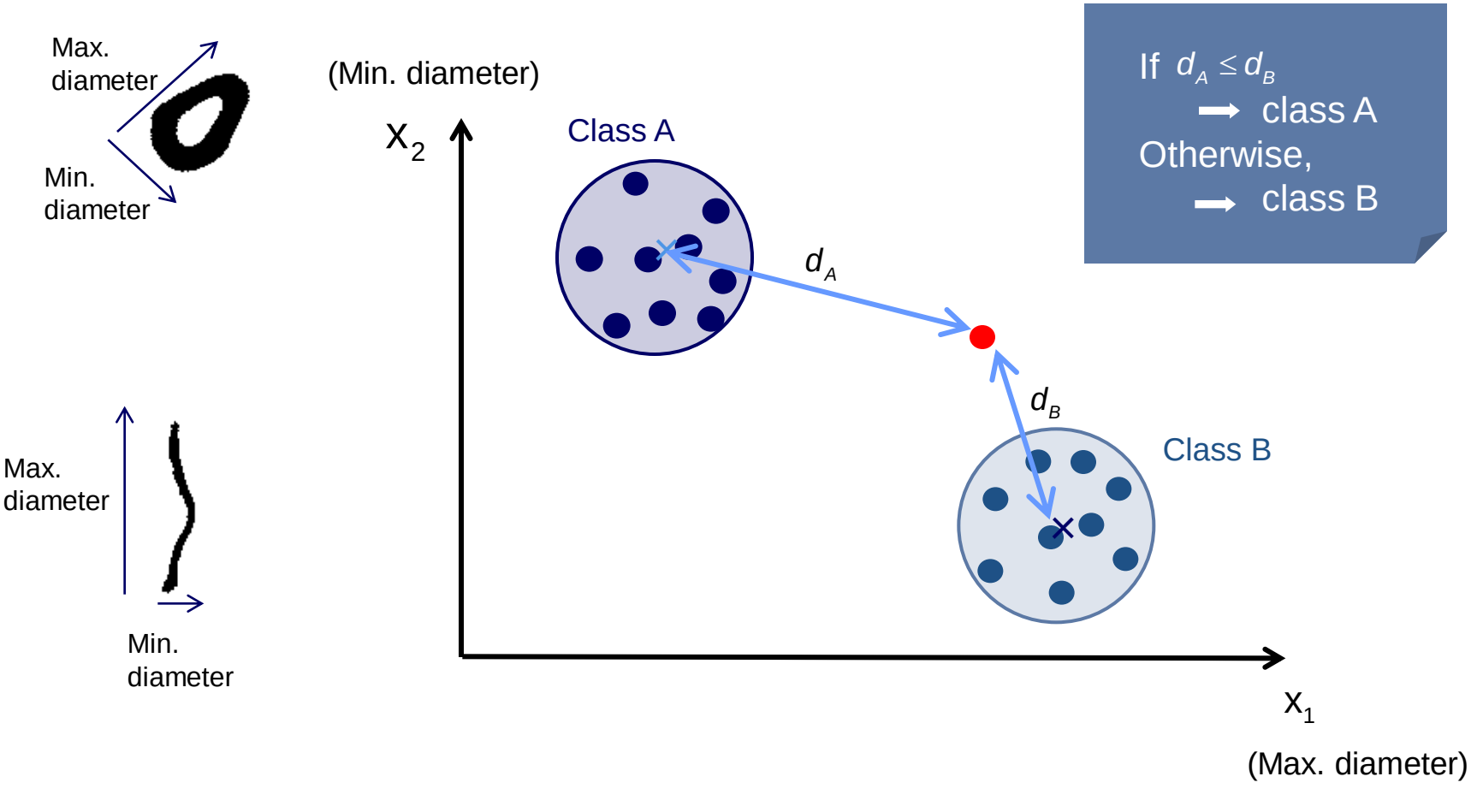
| Shape Descriptor | Formula |
|---|---|
| Area ratio | $\frac{\text{Area(exc.lumen)}}{\text{Area(inc.lumen)}}$ |
| Form factor | $\frac{4\pi \cdot \text{Area(inc.lumen)}}{\text{Perimeter}^2}$ |
| Circularity | $\frac{4\pi \cdot \text{Area(exc.lumen)}}{\text{Perimeter}^2}$ |
| Aspect ratio | $\frac{\text{Major axis}}{\text{Minor axis}}$ |
| Solidity | $\frac{\text{Area(exc.lumen)}}{\text{Convex area}}$ |
| Convexity | $\frac{\text{Convex perimeter}}{\text{Perimeter}}$ |
| Roundness | $\frac{4 \cdot \text{Area(inc.lumen)}}{\pi \cdot \text{Major axis}}$ |




| No lumen object | |
|---|---|
| Shape Descriptor | Formula |
| EPD (Two end points distance) |  |
| | $\frac{\text{EPD}}{\text{Perimeter}}$ |
| | $\frac{\text{EPD}}{\text{Major axis}}$ |

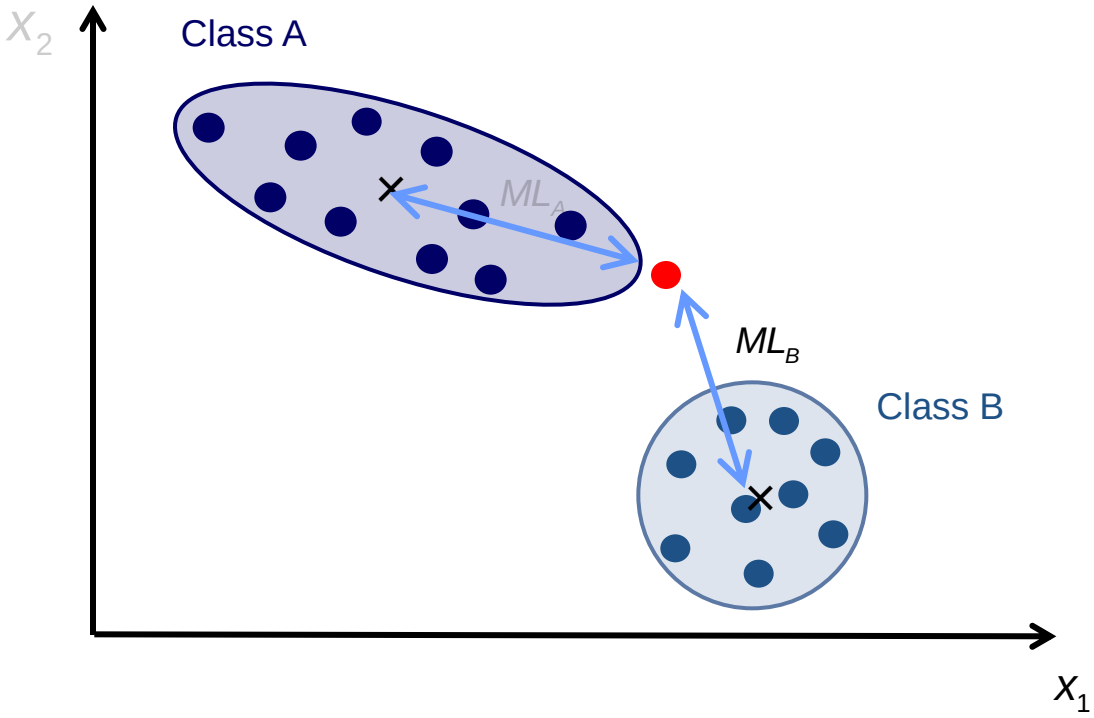
# Discriminant Analysis



# Mahalanobis  Discriminant Analysis (MLDA)

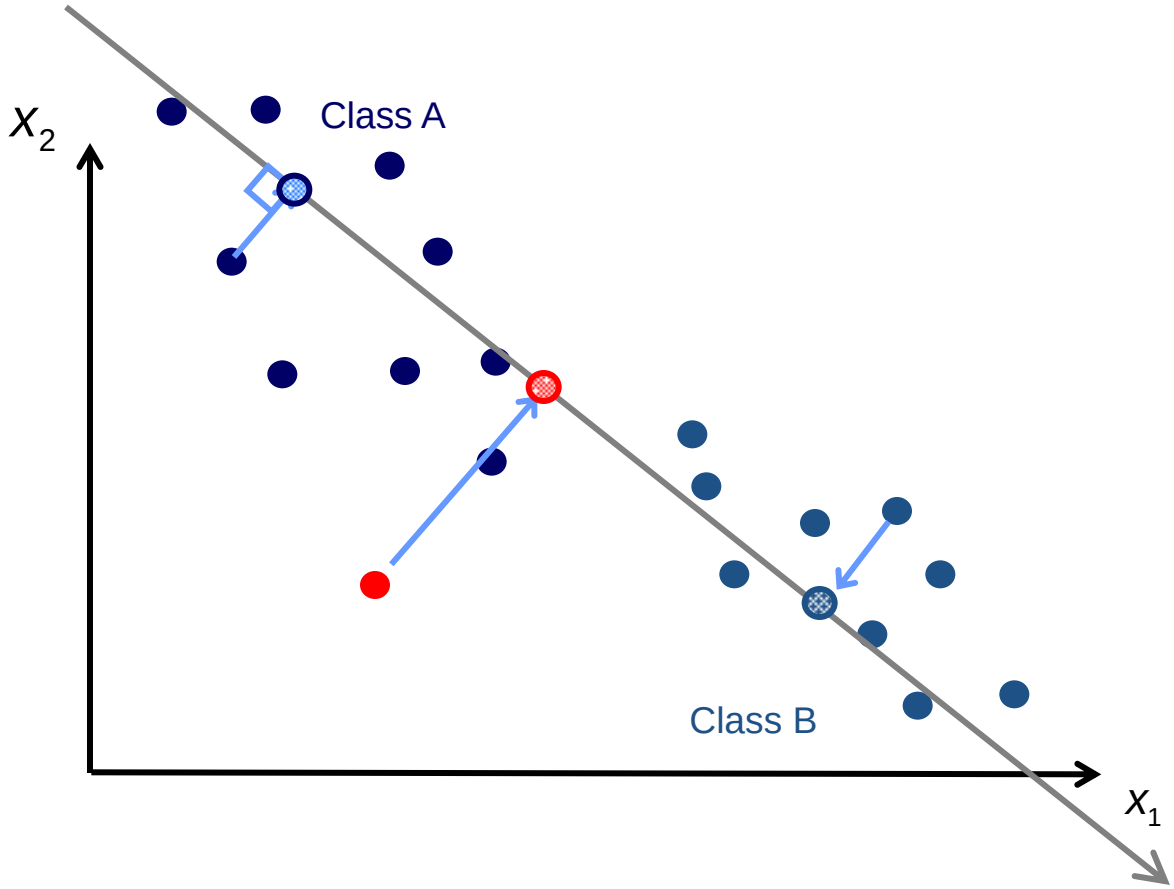
Mahalanobis distance:

distance based on correlations between variables by which different patterns can be identified and analyzed.

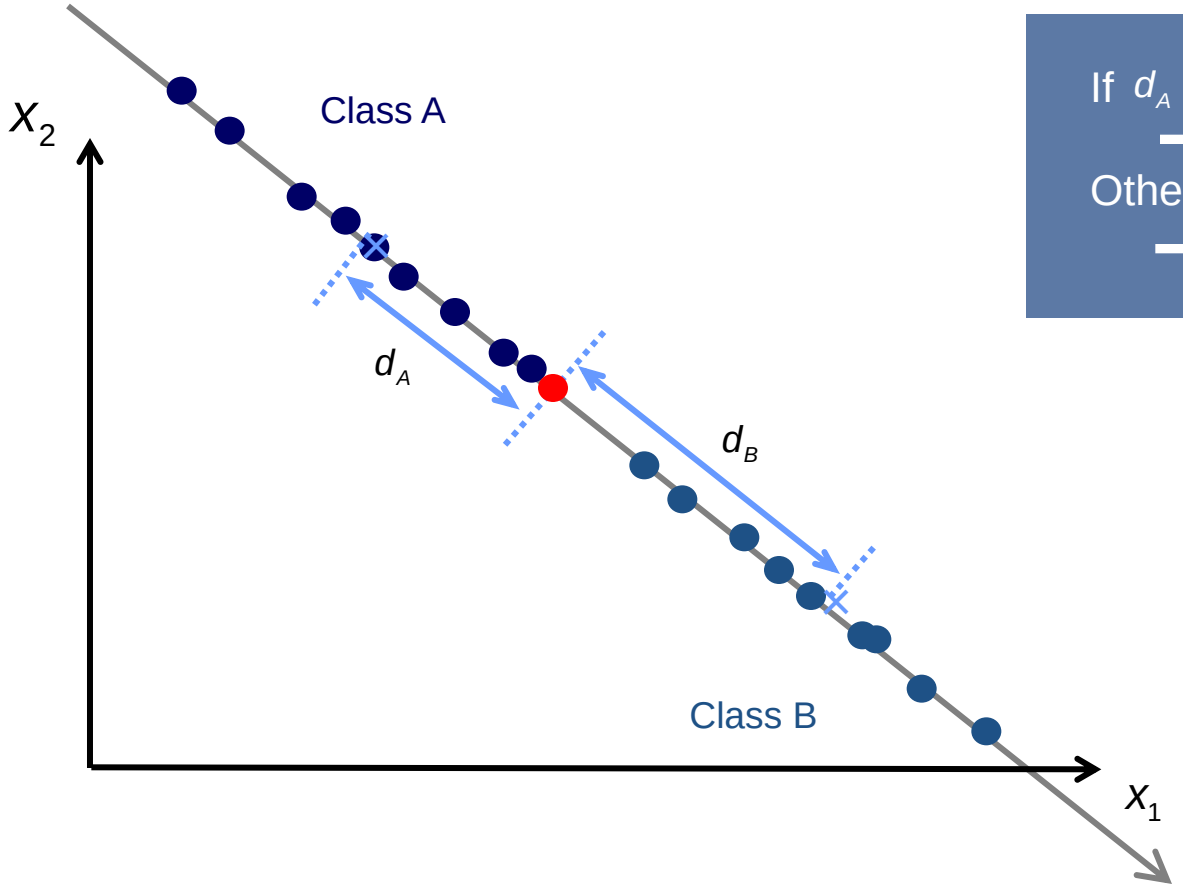



If $ML_A \leq ML_B$
→ class A
Otherwise
→ class B

# Canonical Discriminant Analysis (CDA)



# Canonical Discriminant Analysis (CDA)

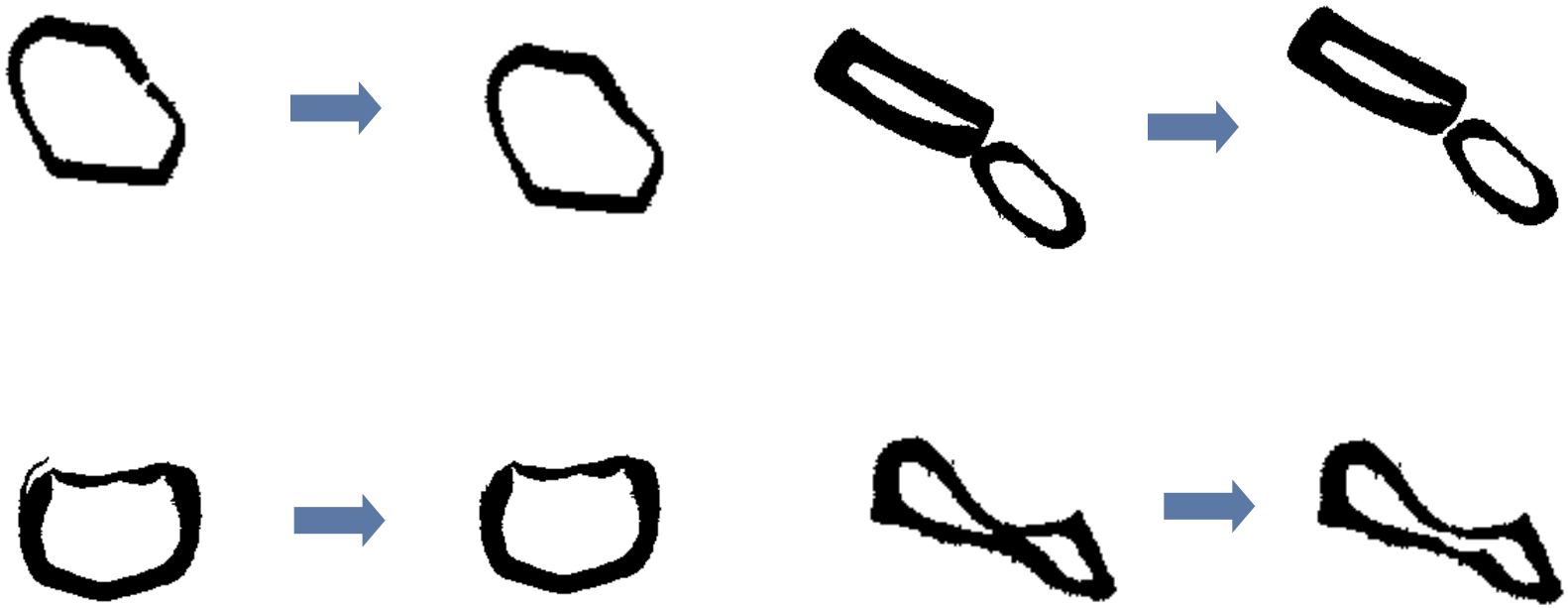



If $d_A \leq d_B$
➞ class A
Otherwise,
➞ class B

# Error Ratios

| | # of training data | MLDA | | CDA | |
|---|---|---|---|---|---|
| | | Training | Checking | Training | Checking |
| No lumen | 608 | 21.8% | 25.5% | 23.2% | 26.4% |
| Single lumen | 895 | 17.3% | 15.9% | 20.1% | 25.8% |
| Multiple lumen | 150 | 16.0% | 31.8% | 50.7% | 50.0% |

# Future work



# Conclusions

- ✓ We have applied MLDA and CDA, to two dimensional image data to classify them by their shapes and compared the results.
- ✓ We adopt MLDA for our future works.
- ✓ The approach presented in this study will form the basis for developing automatic procedures for quantifying wood fibre cross-sectional dimensions and shapes, as influenced by industrial processes in the pulp and paper industry.

# Acknowledgement

The financial support from the Wood Wisdom-Net project, WoodFibre3D, is gratefully acknowledged.

Thank you for your attention !!

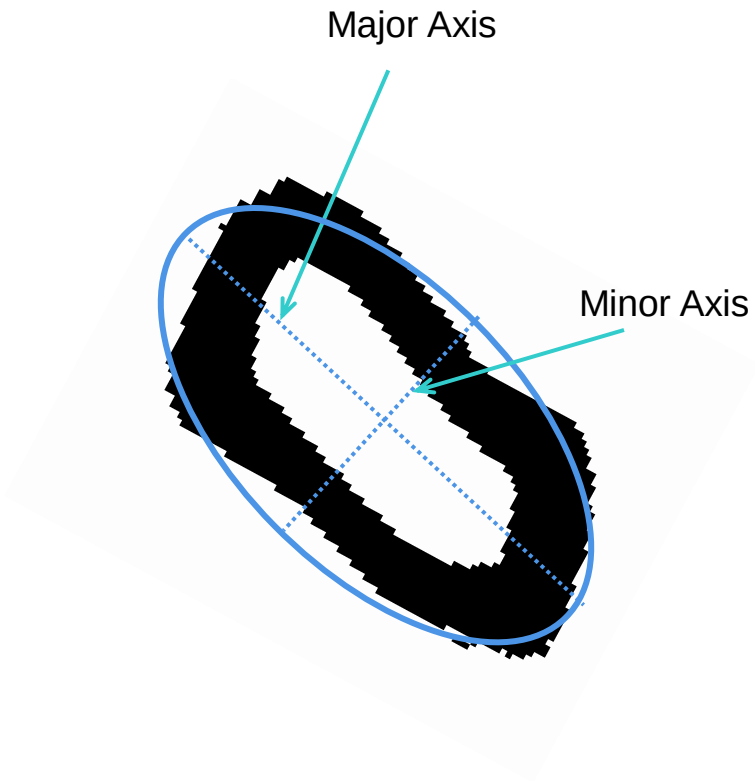
# Classification

| | No lumen | | | Single lumen | | | Multiple lumen | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Discontinuity | Split | Touching | Intact | Shoulder | Touching | Touching | Collapsed | Shive | Shoulder | Fibrlllated |
| Correct |  |  |  |  |  |  |  |  |  |  |  |
| Misclassification by MLDA |  |  |  |  |  |  |  | |  | |  |
| Misclassification by CDA |  |  |  |  |  | |  | |  |  |  |

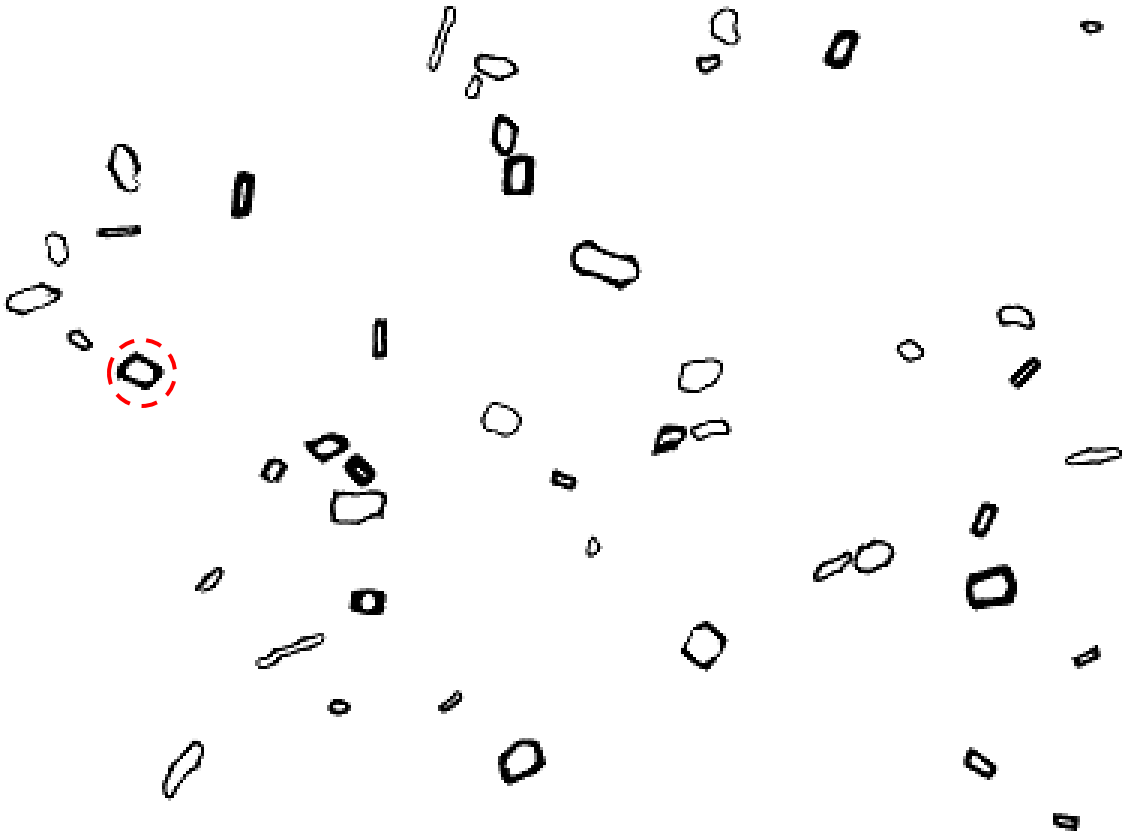
PFI

NTNU

# Ellipse



# MLDA results (intact fibre)



# CDA results (intact fibre)