Université de Liège

Sensitivity of particle size & shape parameters

with respect to digitization

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Liège University (ULg)

A prominent research partner in Belgium

18 000 students - 2000 PhD students
Largest network of spin-off companies in Belgium (>70)

GeMMe – Minerals Engineering, Materials & Environment

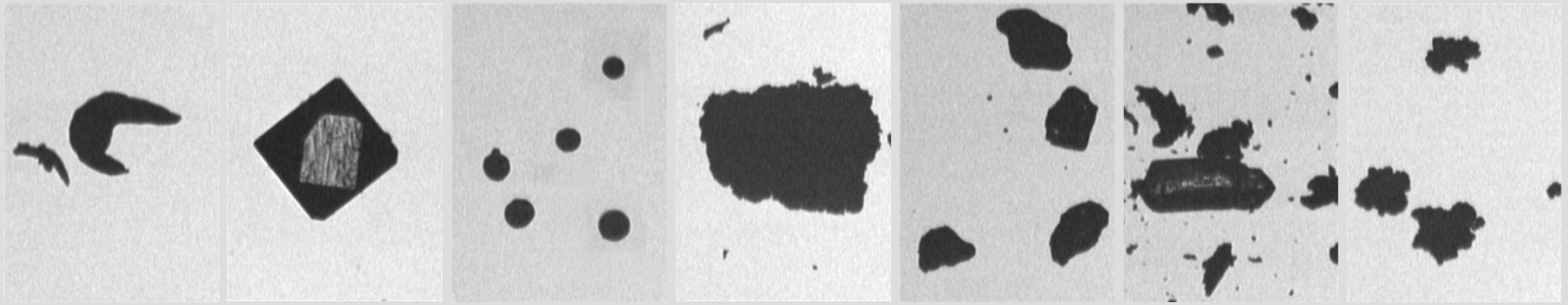
Synopsis

- Introduction
  - Importance of size & shape indices
  - Emerging ISO Standards for IA
  - Exner « quality criteria »
- Material & Methods
  - Sub-pixel digitization
  - Simulated particles
  - Real particles
  - Area-Perimeter-Elongation-Bluntness
- Results
  - Accuracy of size/shape estimators
  - Practical implications
- Perspectives

Introduction

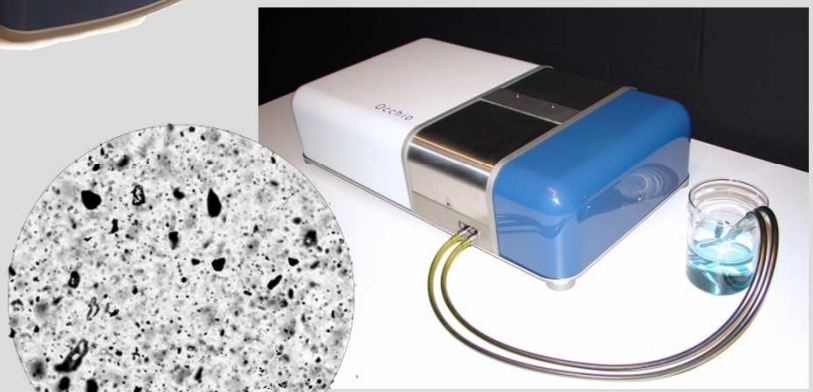
- Importance of size & shape indices
- Emerging ISO Standards for IA
- Exner « quality criteria »

- Importance of Particle Size and Shape



  - Non imaging methods (indirect)
    - Sieving
      - » Weight of particles passing through a square mesh
    - Laser Diffraction
      - » Inversion of a cumulated diffraction pattern as a distribution of spheres
    - …
  - Imaging methods (direct)
    - Image Analysis
      - » Individual pictures of particles
      - » No hypothesis on particle shape
      - » Distributions in « volume » or number

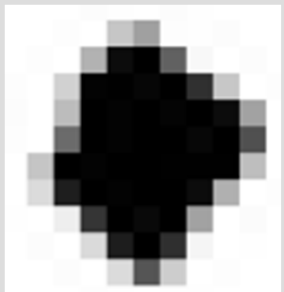
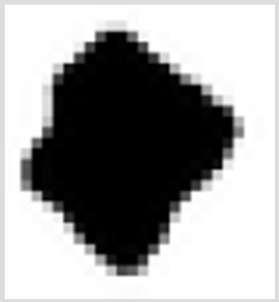
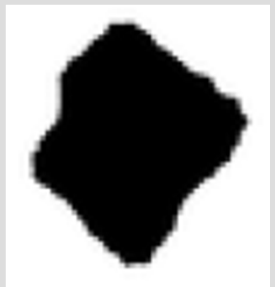
- Maturity of Image Analysis based technologies
  - Dedicated instruments
    - Coarse (50 µm – 5 mm) / Fine (500 nm – 200 µm) powders
    - Wet / Dry powders





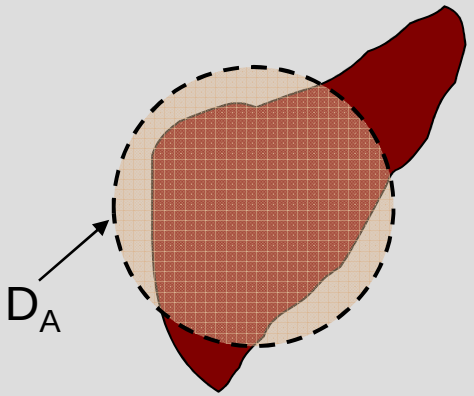



- ISO Standards
  - ISO 13322-1 *Particle size analysis - Image analysis methods*
  - ISO 9276-6 *Descriptive and quantitative representation of particle shape and morphology*
    - ISO parameters are
      - » A trade-off between manufacturers
      - » Ease of computation
      - » Simple definition
    - No recommendations on
      - » Image acquisition (magnification, resolution)
      - » Image segmentation (thresholding).

- Quality of shape parameters *Exner (1987)*
  - Relevance
  - Robustness
  - Independence
  - Sensitivity
  - Additivity
  - Accessibility

ISO Equiv. Area Disk Diameter: $D_A = 2.\sqrt{\frac{A}{\pi}}$



Not a physical dimension of the particle

A lot of decimals… but no precision!

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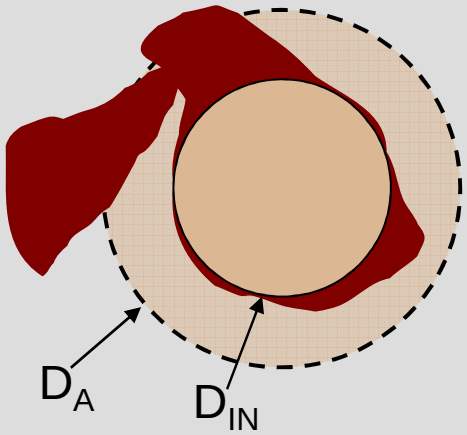
Robustness with respect to touching particles



D_A is twice as large as D_{IN} !

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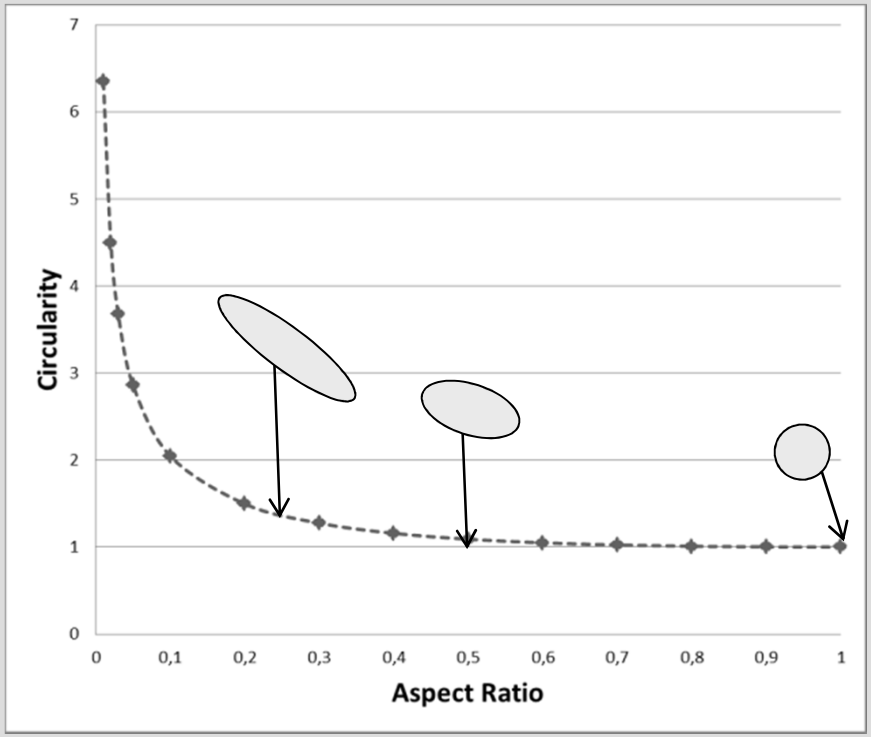

$$F = \frac{4.\pi.A}{P^2}$$

Circularity (= shape factor F) is a function of elongation AND roughness

- Quality of shape parameters *Exner (1987)*

$$F = \frac{4.\pi.A}{P^2}$$

  - Relevance
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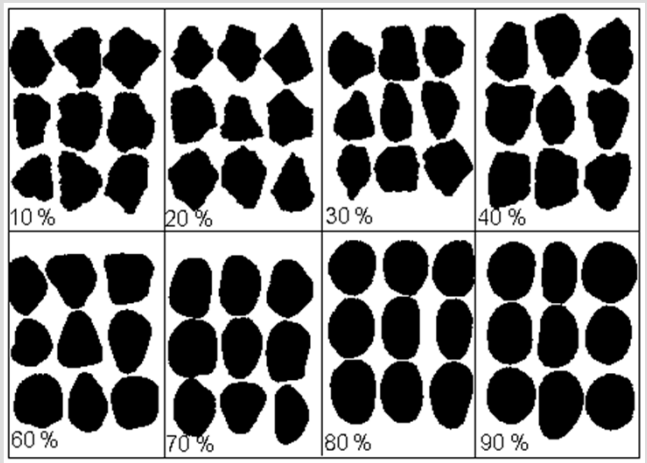
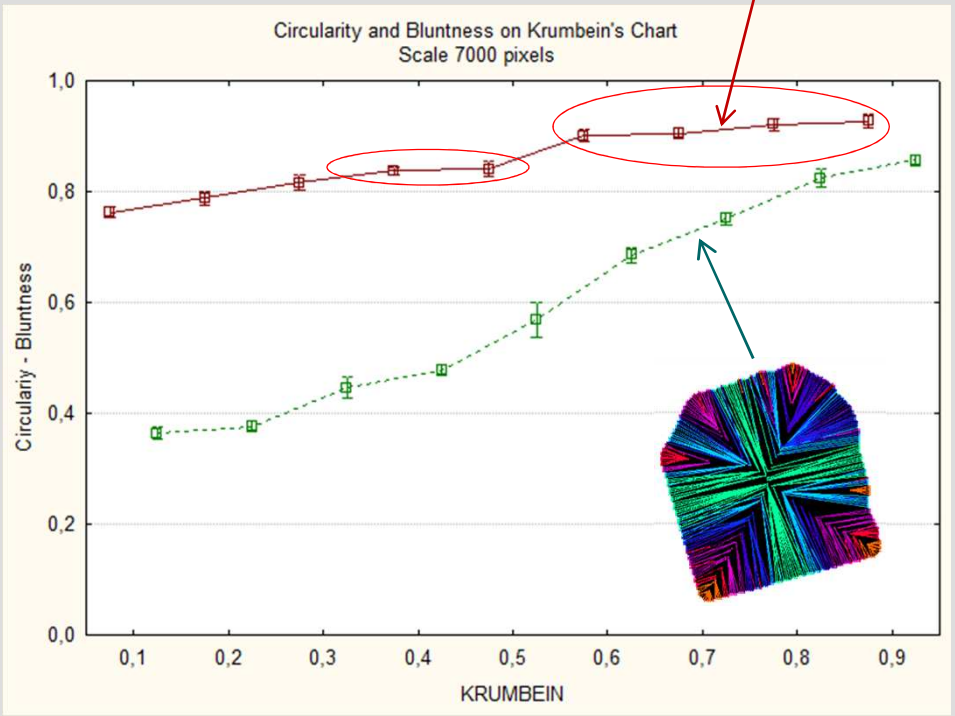




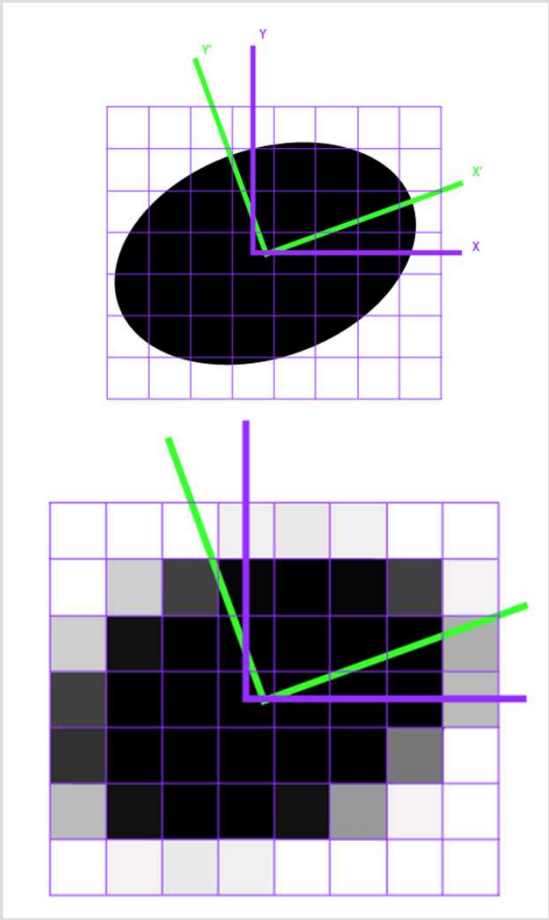





Material & Methods

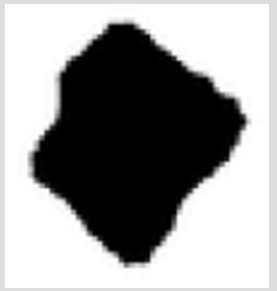
- Sub-pixel digitization
- Simulated particles
- Real particles
- Area-Perimeter-Elongation-Bluntness

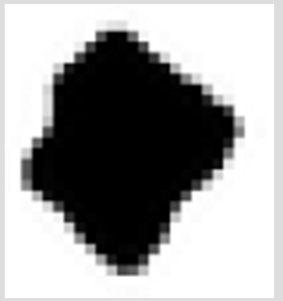
- Simulation of particles
  - Geometric shapes
    - Grid density *(resolution)*
    - Translation
    - Rotation
      - » 16 x 16 subsampling grid
      - » Grey level = Area coverage
    - Threshold

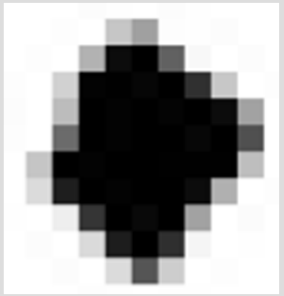


Material & Methods

- Simulation of particles
  - Real shapes
    - Imaging at high resolution
      - » 10 000 pixels/particle
    - Subsampling
      - » 16 x 16 subsampling grid
      - » Grey level = area coverage
      - » down to 100 pixels/particle



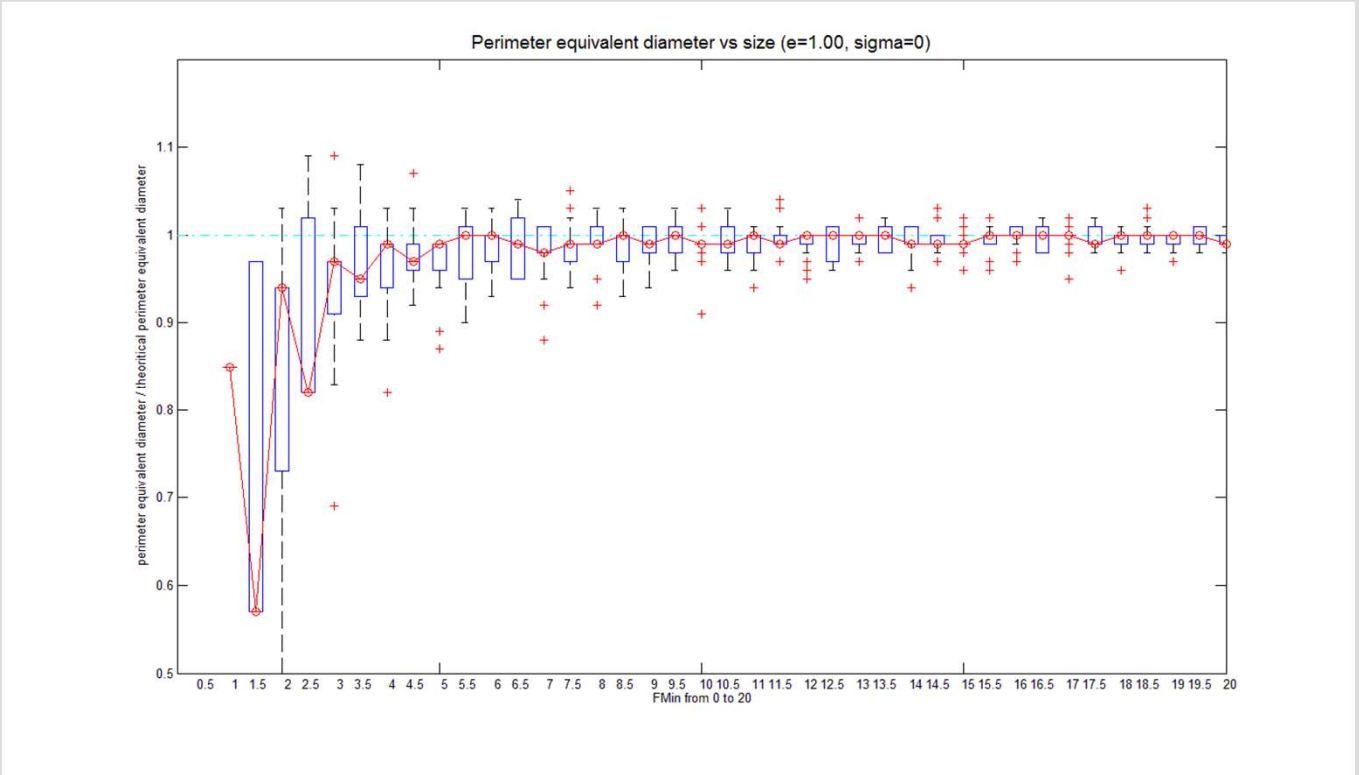




Results

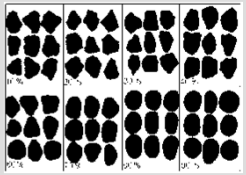
- Evolution of parameter with
  - pixel density
  - Rotation/translation
  - thresholding

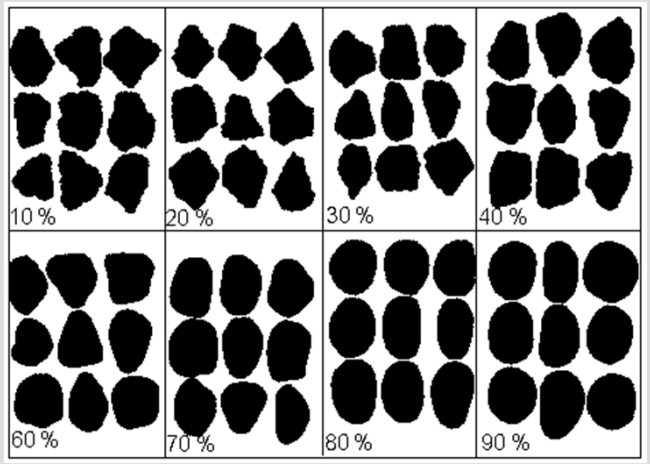
- Perimeter vs Resolution

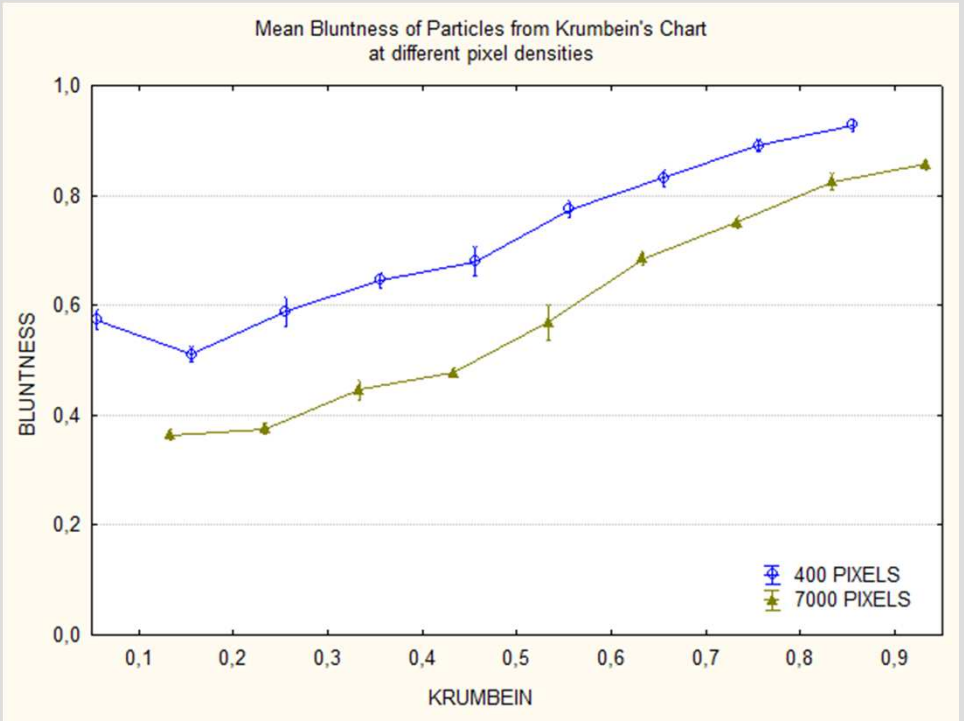


Crofton's perimeter equivalent diameter vs. theoretical diameter as a function of pixel density (from 1 to 20 pixels)

- Bluntness vs Resolution







Perspectives

- Practical Conclusions
  - Pertinence of Exner's criteria
    - » Independence, Sensitivity,…
  - Recommendations of min. resolution for ISO standards
    - » 10 pixels for size
    - » 200 pixels for aspect ratios
    - » 2000 pixels for « roughness »
  - Comparison of shape within narrow size ranges
    - » Be aware of pseudo-correlations
      the « fine is smooth » effect
  - More systematic work on analytical errors in Image Analysis