AE 760AA: Micromechanics and multiscale modeling

Lecture 7 - Physical measurements

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schedule

- Feb 13 - Physical measurements (HW2 Due)
- Feb 18 - Variational Calculus
- Feb 20 - Variational Calculus
- Feb 25 - Bounds and Boundary Conditions

outline

- review
- measuring orientation

review

checking transformations

- Follow the procedure **here**
- This gives a way to systematically check whether your rotations are correct
- You can check any coordinate transformation as long as you know the unit vectors of your primed coordinate system in the global coordinates

$$x = [Q^T]x'$$

common homework errors

- Some people had rotations about an axis with zeros along the diagonal
- This is possible with successive rotations, but for a rotation about one of the three axes, you should always have one term along the diagonal equal to 1
- When calculating stiffness in Problem 2, most students had some unexpected behavior
- All four walls had same x_1 component of fibers, you should have gotten C_{11} the same for all 4 walls
- C_{22} or C_{33} should have also been equal to C_{11}, depending on the wall

measuring orientation

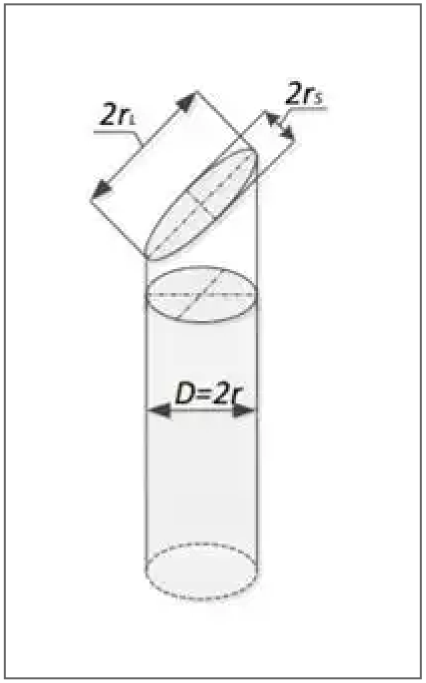
measuring orientation

- In micromechanics (and most places where multi-scale modeling would be used), measuring local orientations can be difficult
- For composites, these are some common techniques
  - Microscopy (some ambiguity in orientation tensor)
  - Serial sectioned microscopy (eliminates ambiguity, very expensive)
  - CT-scanning (only gives approximate measure)
  - Micro CT-scanning (only for very small parts)

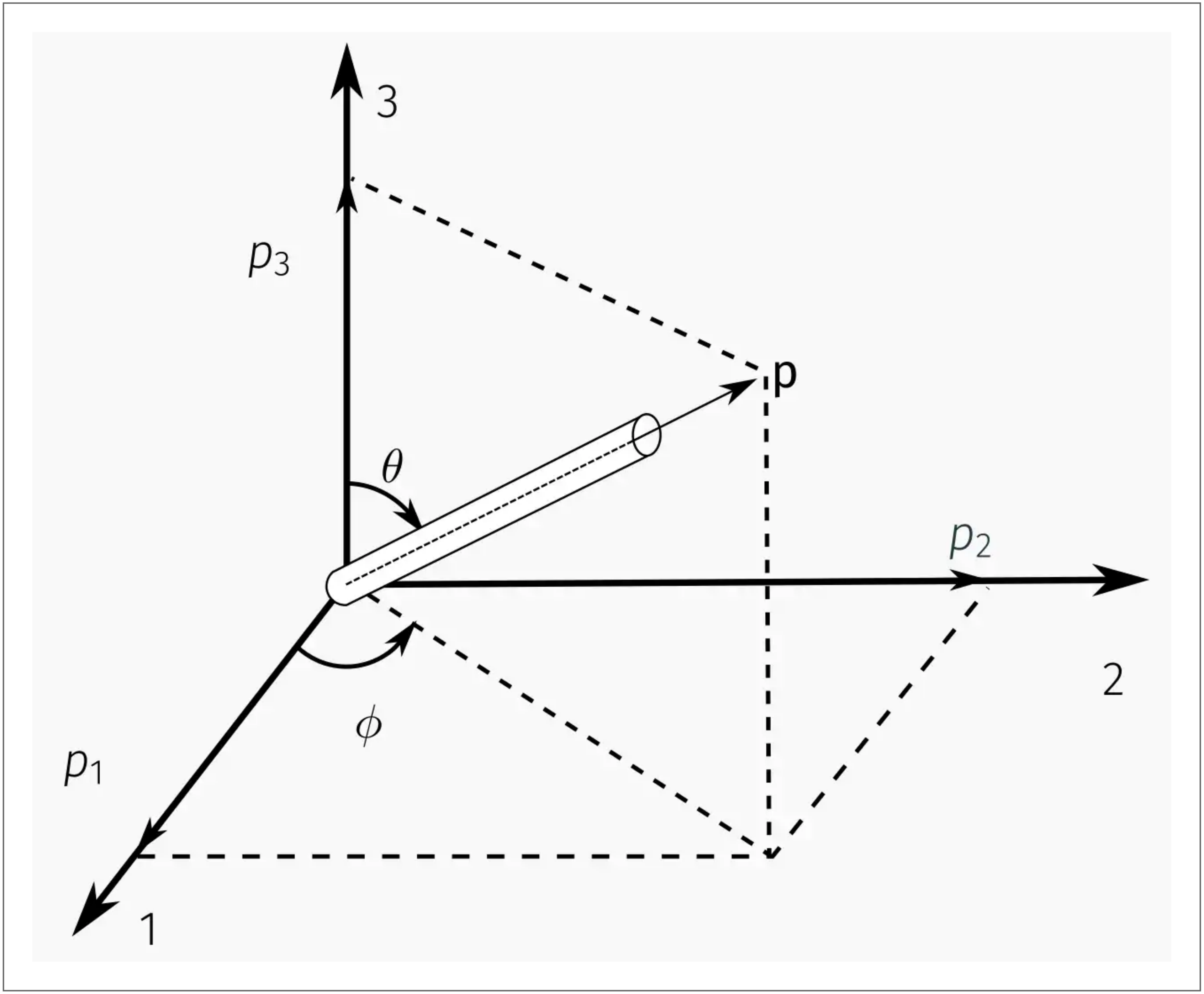
microscopy

- Cylindrical fiber intersects cutting plane at some angle
- After cutting and polishing, this leaves an ellipse
- By measuring the ellipse, we can calculate the angle between it and the cutting plane
- Microscopy can also be used to measure volume fraction, void content, and fiber spacing

microscopy



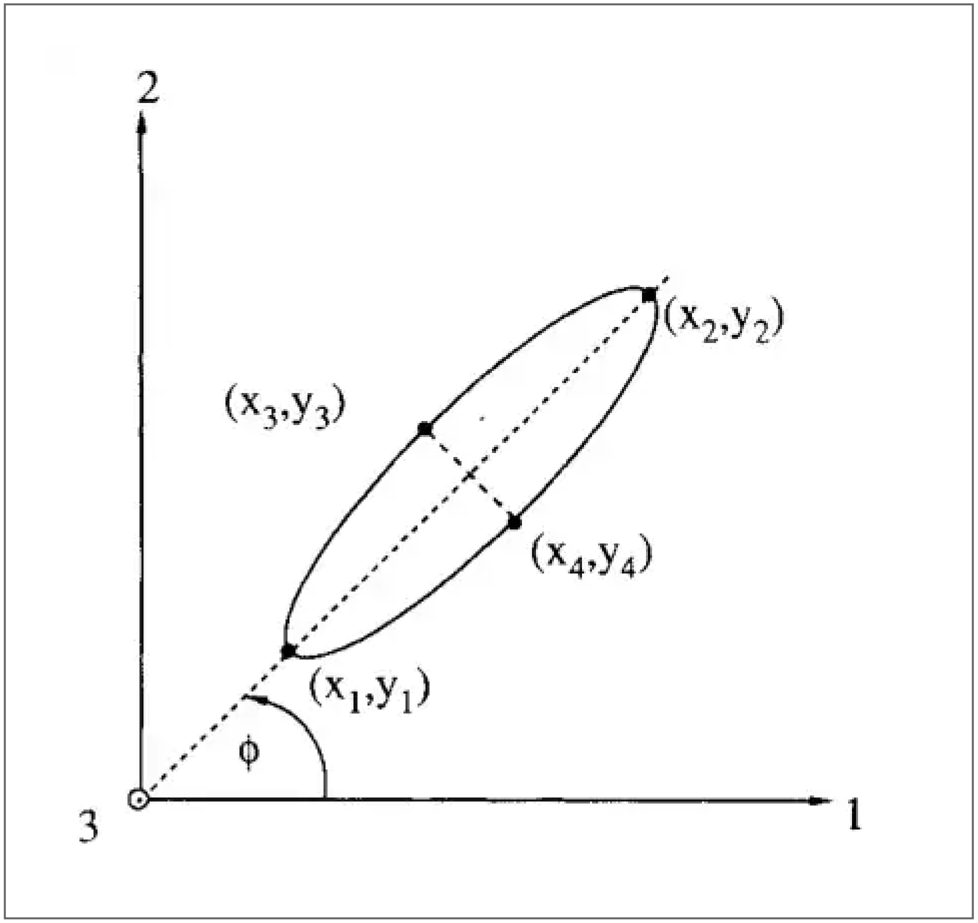
fiber in spherical coordinates


3
p_3
p
θ
p_2
2
ϕ
p_1
1

fiber direction components

Component	**Definition**
p_1	$\sin\theta\cos\phi$
p_2	$\sin\theta\sin\phi$
p_3	$\cos\theta$

measurements



calculations

- We find the major (M) and minor (m) axes using

$$m = \sqrt{(x_3 - x_4)^2 + (y_3 - y_4)^2}$$

$$X = x_1 - x_2$$

$$Y = y_1 - y_2$$

$$M = \sqrt{X^2 - Y^2}$$

orientation tensor

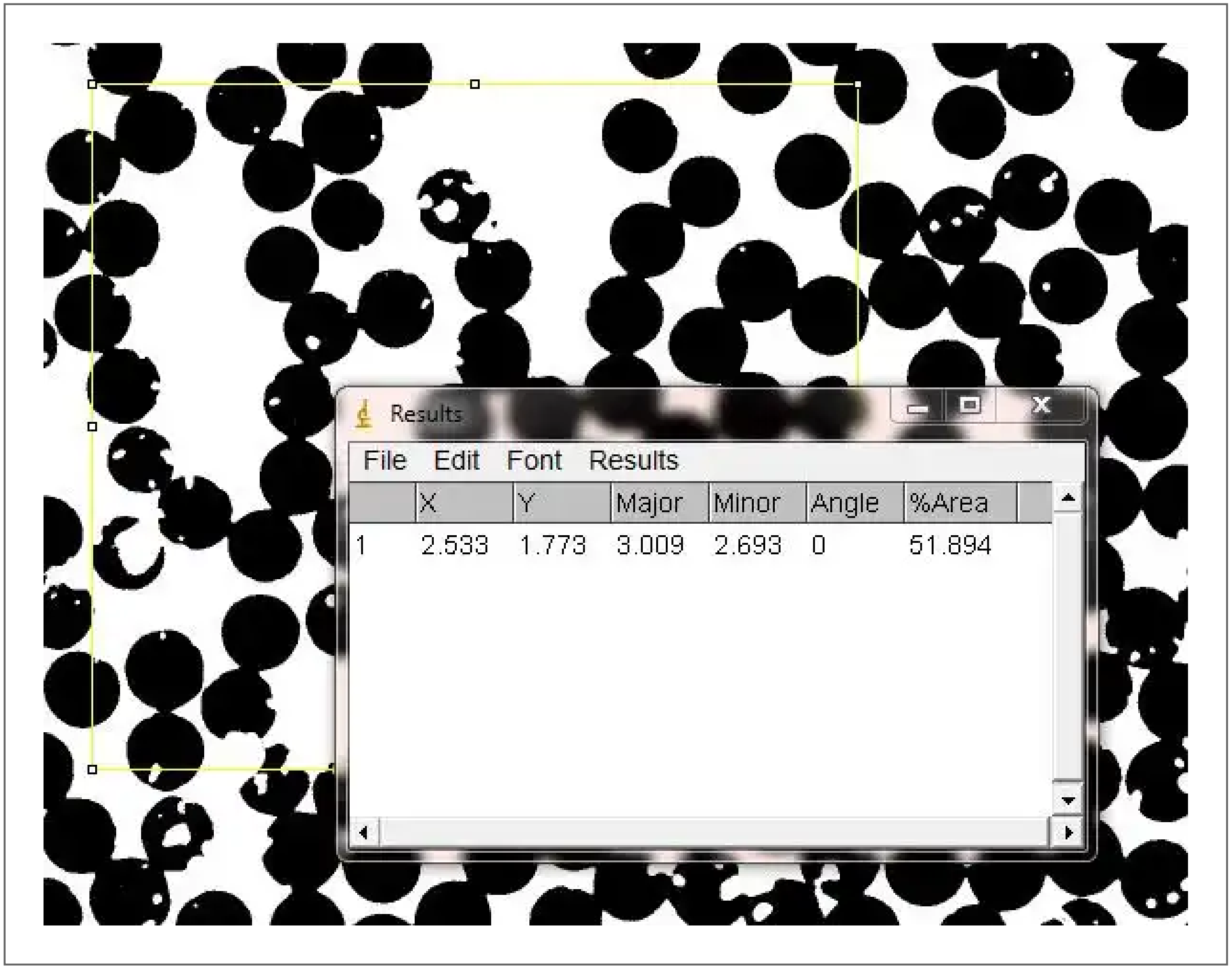
- We can now calculate angles using

$$\sin\phi = \frac{Y}{M}\cos\phi = \frac{X}{M}\cos\theta = \frac{m}{M}\sin\theta = \sqrt{1-\frac{m^2}{M^2}}$$

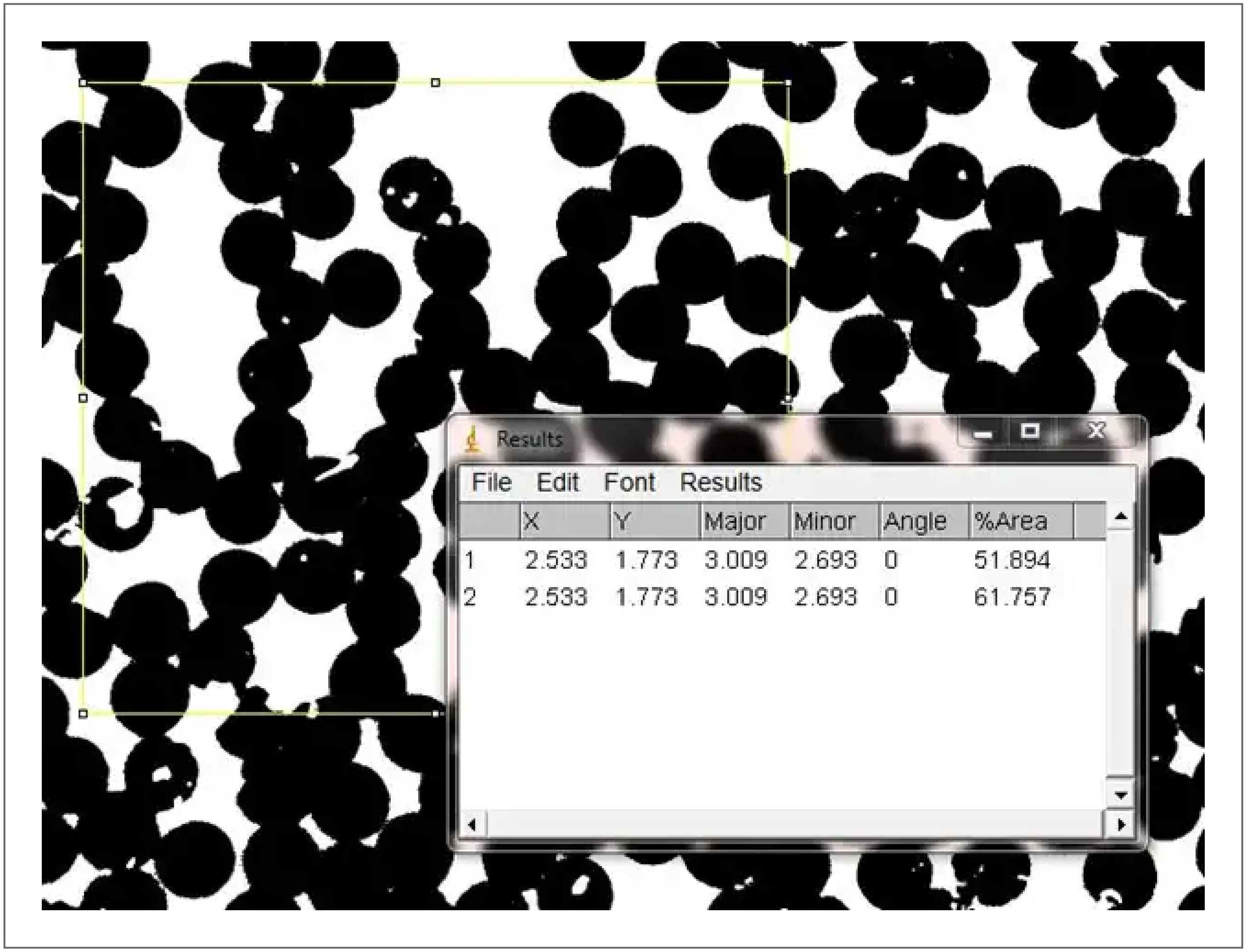
microscopy


100 µm

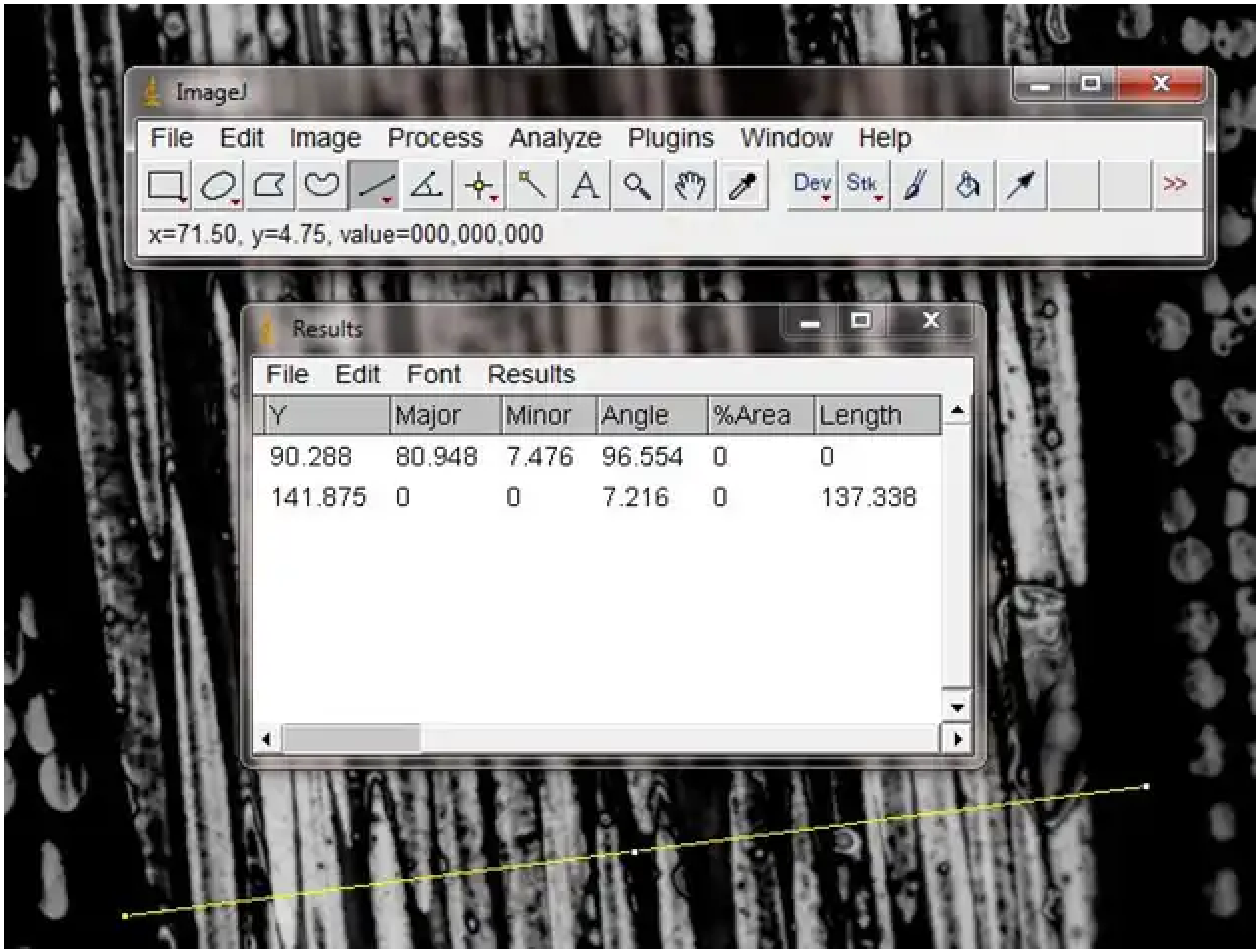
microscopy


Results
File Edit Font Results
X Y Major Minor Angle %Area
1 2.533 1.773 3.009 2.693 0 51.894

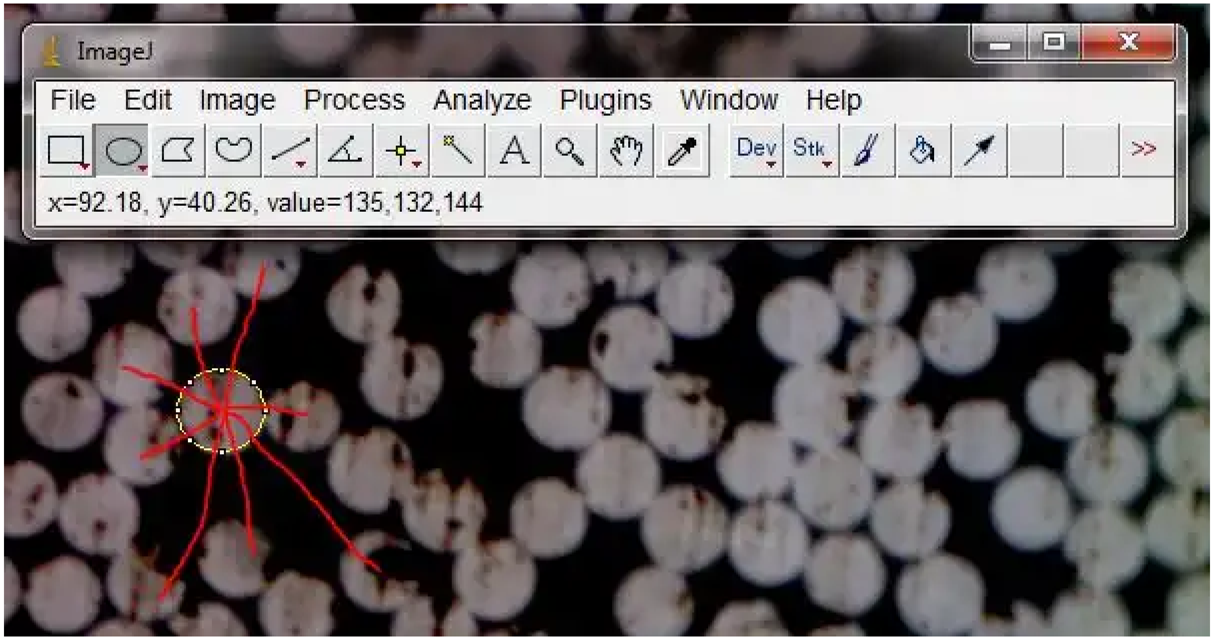
microscopy


Results
File Edit Font Results
X Y Major Minor Angle %Area
1 2.533 1.773 3.009 2.693 0 51.894
2 2.533 1.773 3.009 2.693 0 61.757

microscopy


ImageJ
File Edit Image Process Analyze Plugins Window Help
Dev Stk
x=71.50, y=4.75, value=000,000,000
Results
File Edit Font Results
Y Major Minor Angle %Area Length
90.288 80.948 7.476 96.554 0 0
141.875 0 0 7.216 0 137.338

microscopy


ImageJ
File Edit Image Process Analyze Plugins Window Help
Dev Stk >>
x=92.18, y=40.26, value=135,132,144

software

- If you have to do a lot of microscopy measurements, contact Dr. Sharma, he wrote an automated measurement tool
- Otherwise you can use **imageJ**

microscopy

- Need to account for bias in measurement (more likely to see fibers coming out of plane)
- There is some ambiguity in fiber angle
- Fiber at (ϕ, θ) is not distinguishable from $(\phi + \pi, \theta)$
- In the second-order orientation tensor, this affects a_{23} and a_{13}

serial sectioning

- Serial sectioning is a method where you continually polish a specimen after photographing it
- After photograph you grind and polish, then photograph and repeat
- Gives the full 3D state of orientation, but is difficult

CT Scanning

- Even if a CT Scan cannot resolve down to fiber resolution, the gradient information can give an idea of fiber orientation
- This method is not very precise
- But it can view the full-field and detect many forms of damage without destroying a part
- At the micro-scale full orientation can be obtained, but this is not practical for large parts