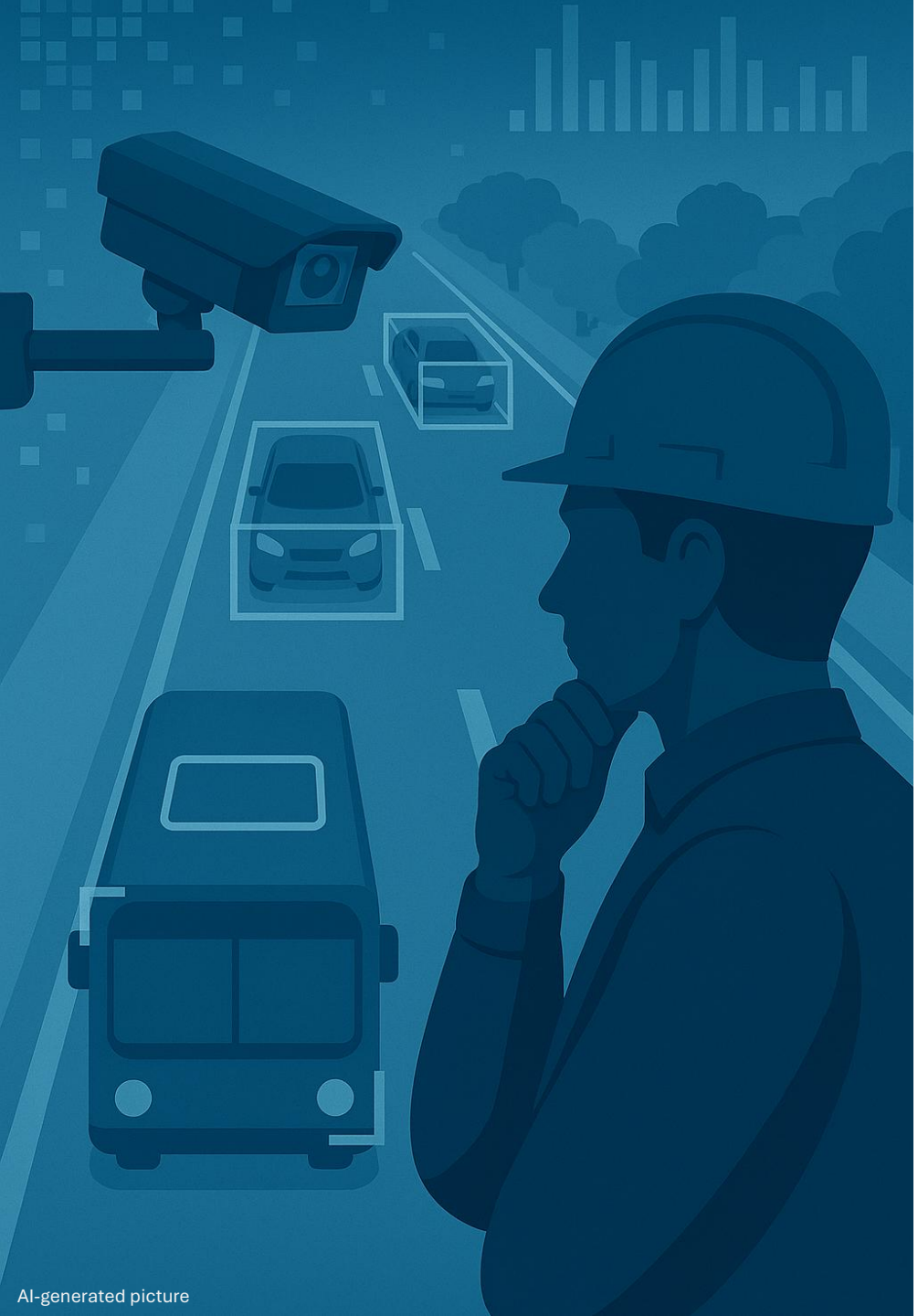

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Image Processing for Transportation Engineering Applications – Part 2

2101553: Computer Applications in Transportation

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Learning Objectives

By the end of this class, you will be able to:

- Explain fundamental concepts of image processing
- Recognize real-life and transportation-specific image processing use cases
- Perform basic image processing tasks using MATLAB

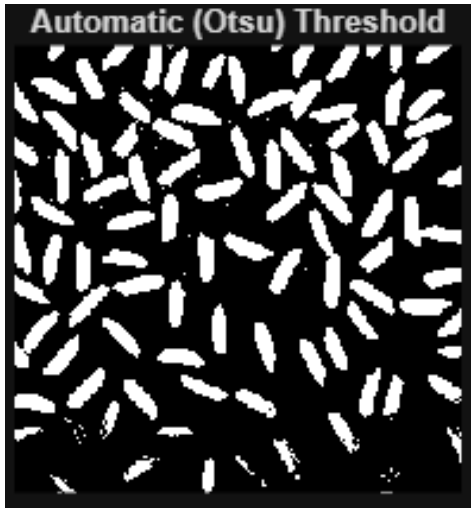
Outline

- Section I: Image Cleaning and Object Analysis
- Section II: Hands-on Coding!

Section I:
Image Cleaning and Object Analysis

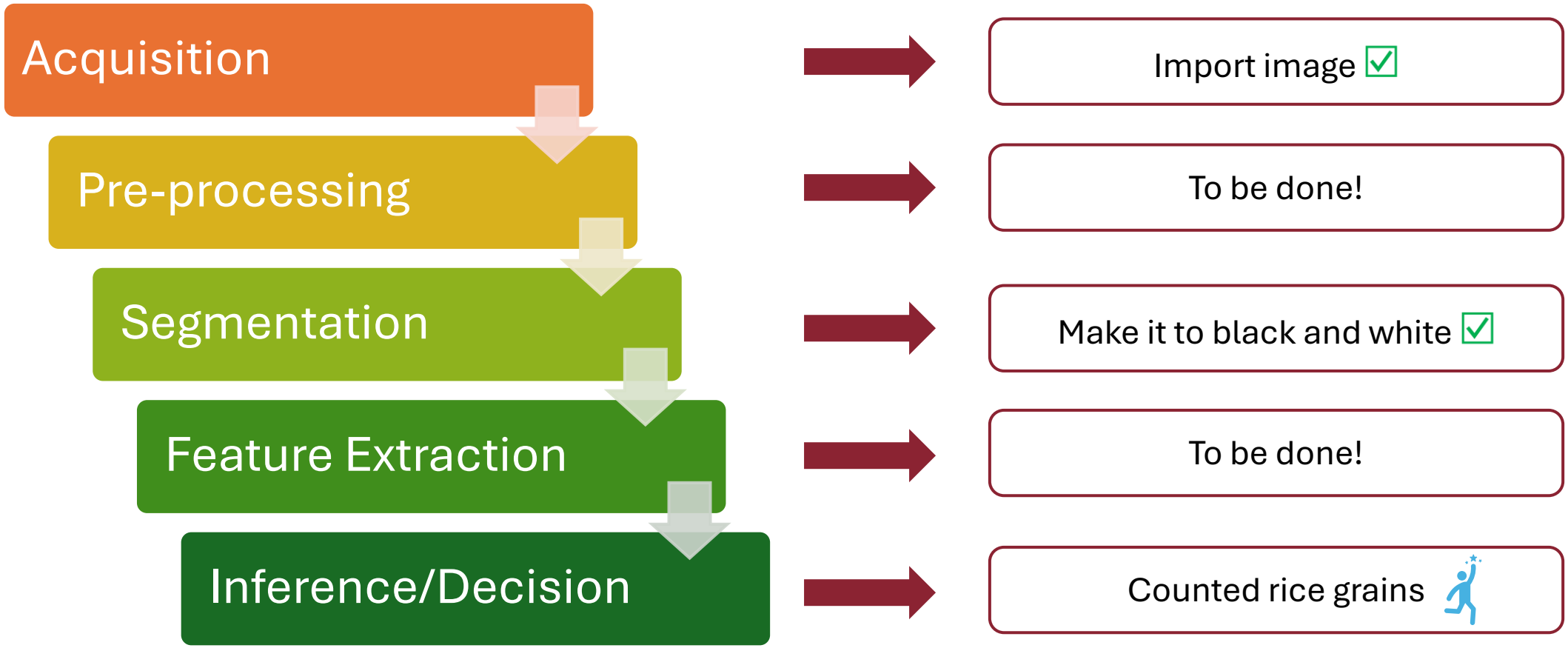
I: Where We Left Off...

- Last week, we learned how to load an image, see it as a 2D matrix, and segment it
- But we were left with a "noisy" mask
  - Small white specks in the background (noise)
  - Small black holes inside the rice grains
- We can't count the rice yet. Today, we will learn how to clean this mask and get an accurate count



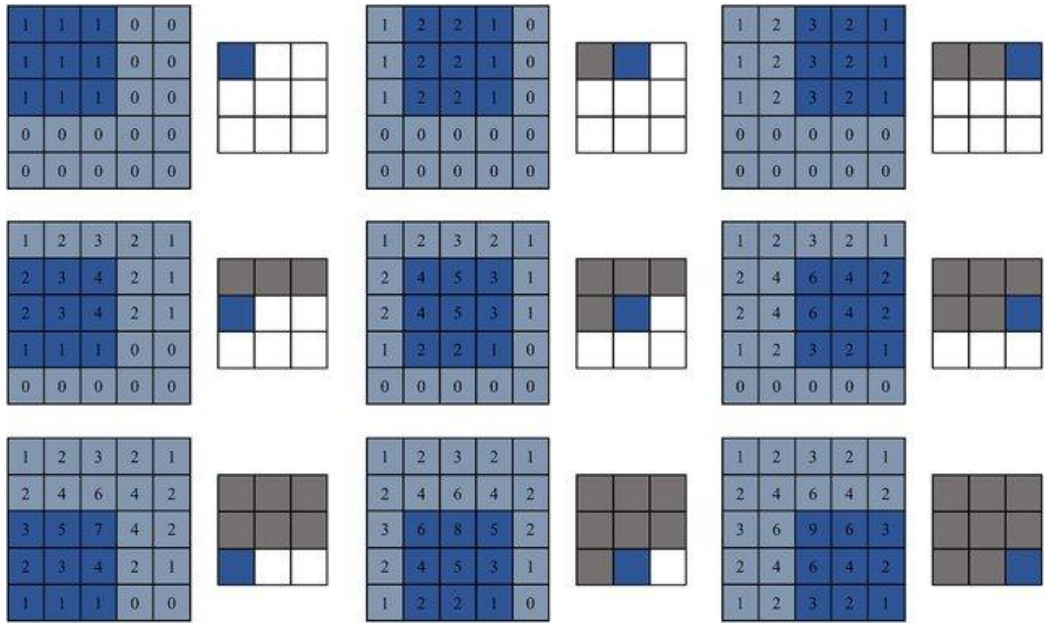
I: Goal – Solve the problem using The Full Pipeline

Counting rice grain pipeline



I: Pre-processing (filtering)

- A **filter** is a **local operation** that recalculates each pixel's value based on its immediate neighbors. It does this using a **Kernel**.
- A kernel is just a small matrix that slides over every pixel of your image. The new pixel is a *summary* of what the kernel sees.

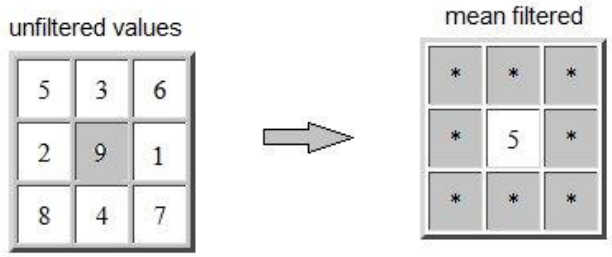


10.1007/s11760-022-02339-4

I: Pre-processing (filtering)

Mean filtering

- Replaces the pixel with the average of its neighbors.
- Blurs the image. It's bad at salt-and-pepper noise; it just smears the white speck into a gray blob.

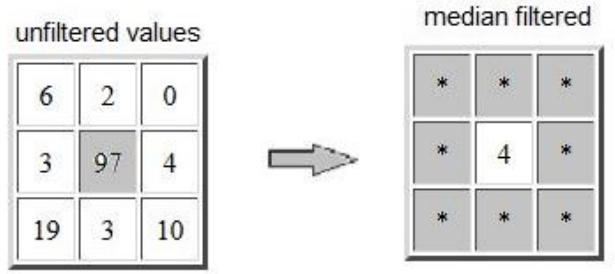


5 + 3 + 6 + 2 + 9 + 1 + 8 + 4 + 7 = 45
45 / 9 = 5

10.13140/RG.2.2.20967.27049

Median filtering

- Replaces the pixel with the median (the middle value) of its neighbors.
- The "salt" (white speck) or "pepper" (black speck) is an outlier, so the median ignores it.



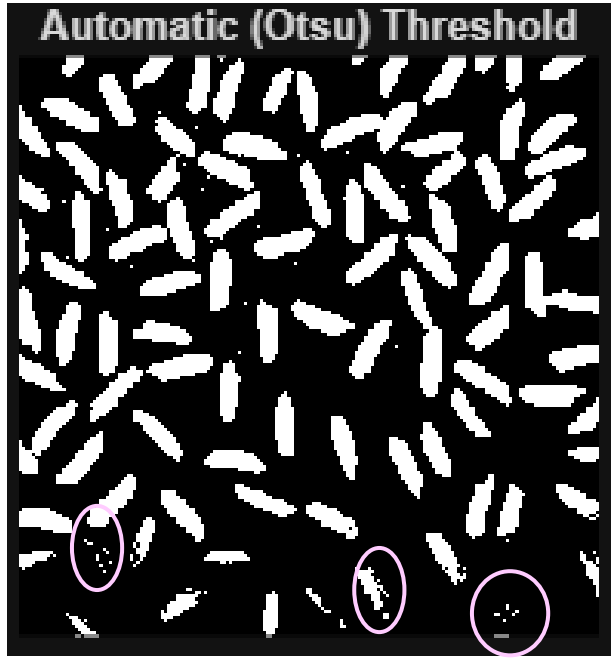
in order:
0, 2, 3, 3, **4**, 6, 10, 15, 97

10.13140/RG.2.2.20967.27049

The median filter is excellent at removing this type of noise while preserving the sharp edges of our rice grains.

I: The Problem - A Messy Mask

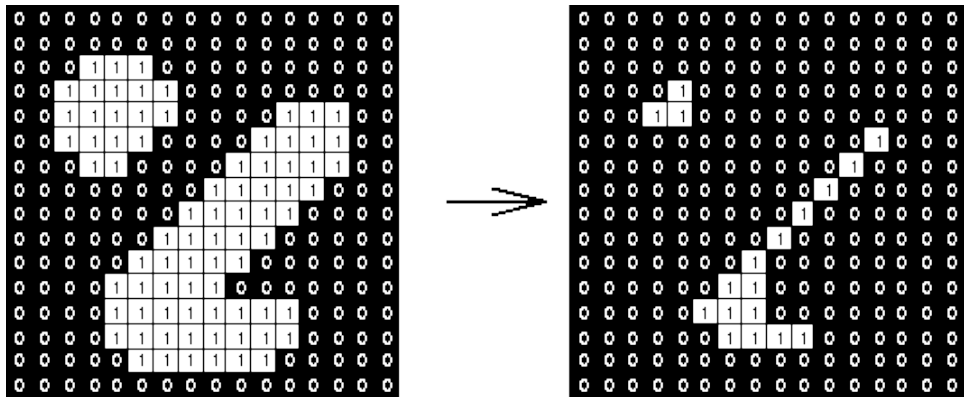
- Result from segmentation is “Binary Mask”
  - It's the black-and-white image that we created
  - Think of it as a stencil:
    - White pixels (1) = Foreground (The rice we want to analyze)
    - Black pixels (0) = Background (The parts we want to ignore)
  - However, our mask is "messy“
- We use Morphological Operations.
  - These are special functions that work on the shape of the white pixels to refine them



I: Morphology - The Building Blocks (Erode & Dilate)

Erosion

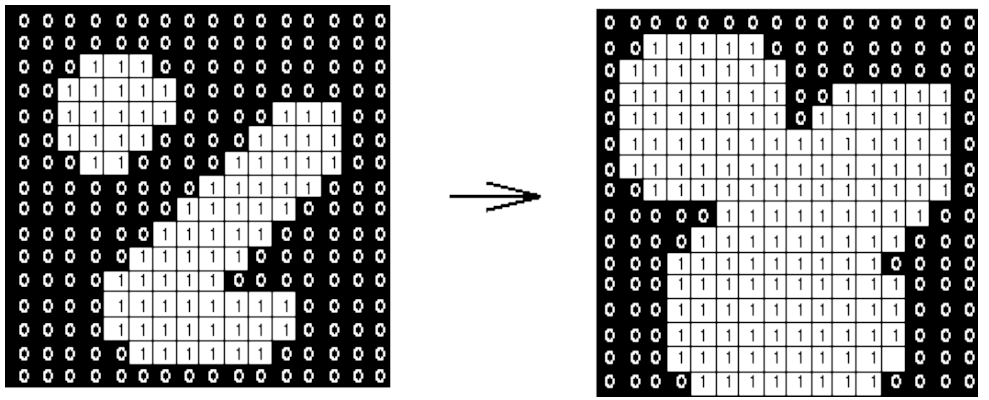
- "Shrinking" or "thinning" the white regions.
- Slides a kernel over the image. A white pixel is kept only if the entire kernel fits inside the white region.
- Small "islands" of noise disappear completely.



https://homepages.inf.ed.ac.uk/rbf/HIPR2/erode.htm

Dilation

- Expanding" or "growing" the white regions.
- If any part of the kernel touches a white pixel, the center pixel becomes white.
- Small "holes" inside objects get filled in.



https://homepages.inf.ed.ac.uk/rbf/HIPR2/dilate.htm

I: Morphology - The Smart Combos

We rarely use just Erode or Dilate, as they change the object's size.
Instead, we use smart combinations.

Image Opening

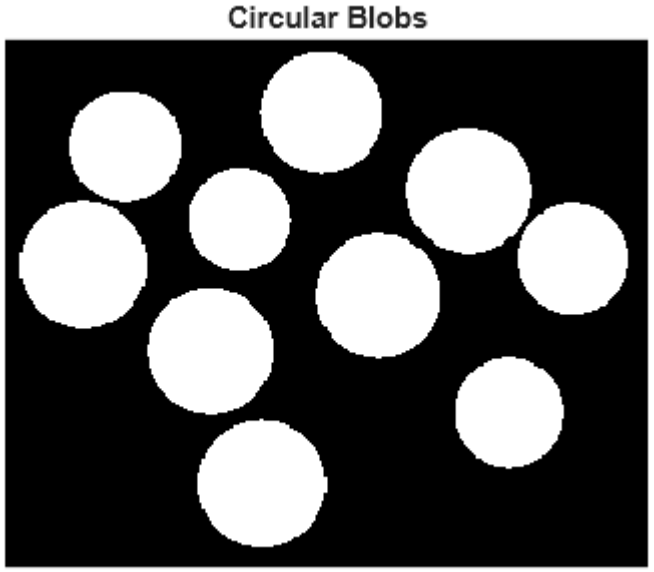
- Erosion followed by Dilation
- Like "Sandblasting." It "erodes" away the small noise specks, then "dilates" the main objects back to their original size.
- Removes background noise. (This fixes the specks outside the rice).

Image Closing

- Dilation followed by Erosion.
- Like "Paving." It "dilates" to fill the small holes inside the objects, then "erodes" the main objects back to their original size.
- Fills object holes. (This fixes the specks inside the rice).

I: Analysis – From Binary Mask to Data

- Result from Morphology should be “Clean Mask”
- Now, it’s time to turn the pixels into data, considering them as a “blob”
- Blob (of pixels) is a group of neighboring pixels that all share the same property, like being the same color.



https://www.mathworks.com/help/vision/ug/find-statistics-of-circular-blobs-in-image.html

I: Analysis Steps

- Step 1: Finding Blobs
  - Scans the binary mask and finds all separate "blobs" (or "components") of white pixels that are touching.
  - A list of all the blobs is made. We will get our rice count from this one function

- Step 2: Measuring Blobs
  - The "magic" function.
  - It takes the list from step 1and measures properties for each blob.

I: Beyond Counting - What Else Can We Measure?

- Each blob = a measurable object

- Typical metrics:
  - Area / Size → how large the object is
  - Perimeter / Length → boundary detail
  - Aspect Ratio → shape (long, round, irregular)
  - Orientation → dominant direction
  - Centroid → position or alignment

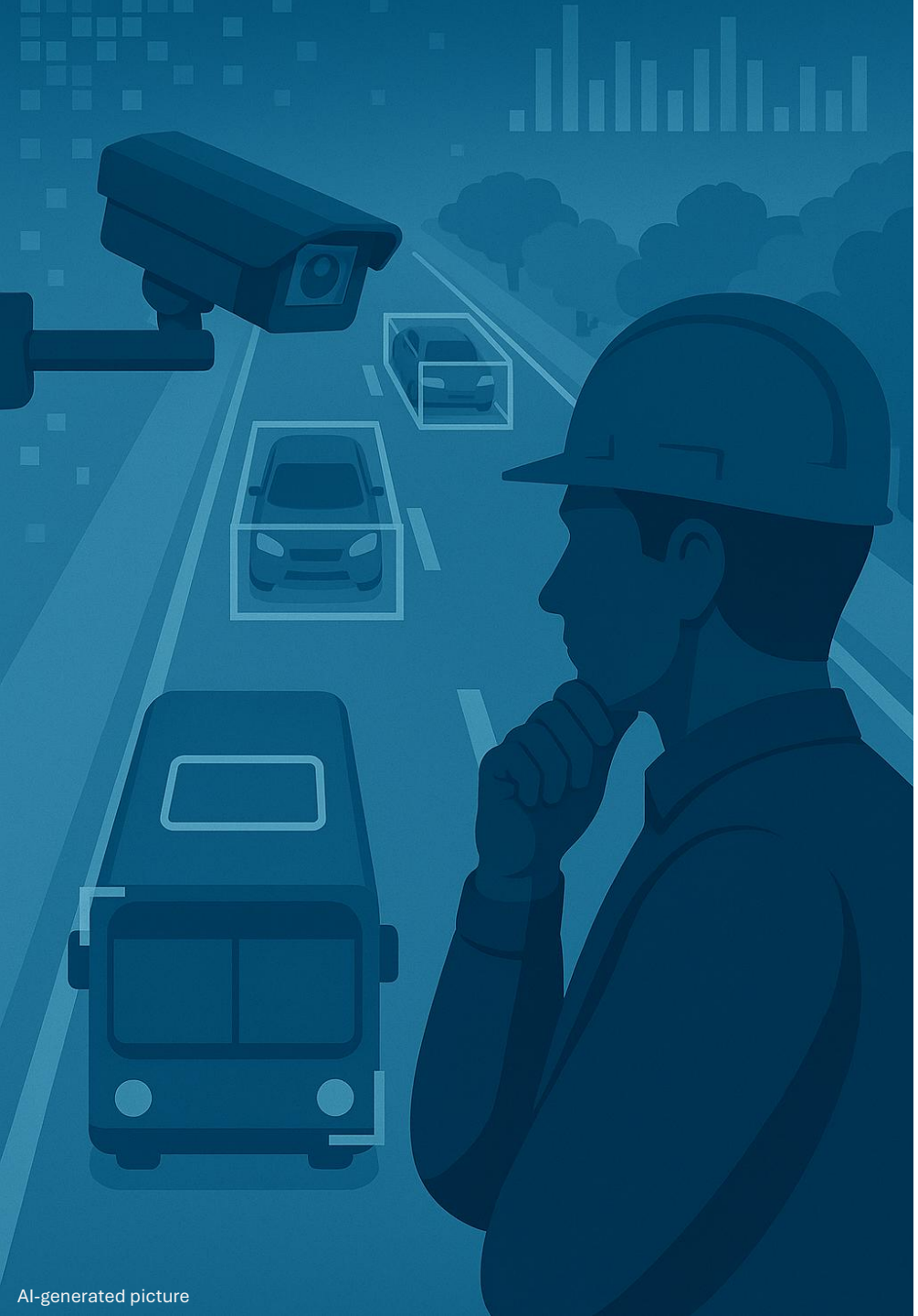
I: From Rice to Real Life

- The same **5-stage workflow** (Filter → Segment → Clean → Analyze → Measure) can apply to:
  - Pavement crack, pothole detection
  - Counting vehicles, bicycles from video
  - Detecting sleepers, missing fasteners
  - Monitoring crowd density at stations
  - Recognizing traffic signs or signals

What else can we do?

Which of these do you think is most difficult, and why?

Section II:
Hands-on Coding



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Thank you for your attention!

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